Vol. 55 No. 1 July 1961

Quarterly

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of the

NATIONAL FIRE PROTECTION ASSOCIATION

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Vol. 55 No. 1 — **JULY 1961**

Table of Contents

Ayer, Massachusetts, Multimillion Dollar Fire ..... Frontispiece

Underground Storage of Liquefied Petroleum Gas
A. F. Dyer and J. W. Hale, Phillips Petroleum Company 5

An Architect Speaks on Fire Protection
William A. Halsey, Bastille Halsey Associates 17

A Fire Protection Engineer Responds to Mr. Halsey
Frank H. Gage, Gage-Babcock and Associates, Inc. 20

Forest Fire Laboratories 22

The Madrid Eyeglass Factory Fire
F. Antonio Salas and Norman R. Wypruk 23

Institutional Fire Protection Is Different
Rexford Wilson, Fire Record Editor, NFPA 28

Anniversary of London's Tooley Street Fire 37

Problems of Water Supply
John W. Cramer, American Water Works Association 38

Interior Finish for Life Safety from Fire
Robert S. Moulton, Consulting Fire Protection Engineer 43

Sprinklers for Palletized Whiskey Barrels
Underwriters' Laboratories, Inc., and Factory Insurance Association .. 51

Army Helicopter Accidents Involving Fire
Capt. Cecil H. Grimes, Army Board of Aviation Accident Research 60

Meetings of the Board of Directors 71

Pressure Tanks for Sprinkler Installations
H. Hoyle, Mather & Platt Limited, Manchester, England 76

Three Service Station Explosions 85

Chemical Plant Waste Incinerator
Charles L. Sercu, Dow Chemical Company 90

Advertising Index 96

Articles and accounts of fires appearing in the Quarterly are based on material forwarded to the Association. The Association, as a body, does not assume responsibility for the accuracy of the material printed herein.

This publication is indexed by Engineering Index, Inc.

Peter J. Conway

The two principal industries in Ayer, Massachusetts, employing 414 persons, were wiped out by a multimillion dollar fire on June 5, 1961. Six exposed dwellings were also destroyed. Details of the fire and its economic effects on the community of 6,000 are being investigated and will be reported in a future issue of the QUARTERLY.

Underground Storage of Liquefied Petroleum Gas

By A. F. Dyer and J. W. Hale, Technical Representatives

Phillips Petroleum Company

From a very small beginning in the 1920's, the liquefied petroleum gas industry grew consistently until about 1940. Since that time, it has shown a very rapid growth, reaching nearly ten billion gallons in 1960. Figure 1 shows

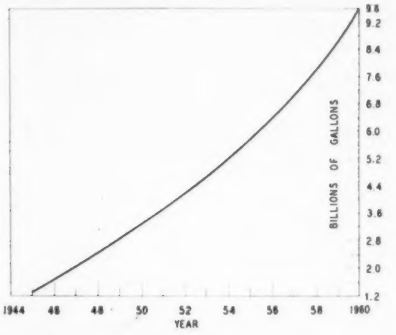


Figure 1. LP-Gas sales, 1945-1960.

the growth pattern of the industry during the past fifteen years (1945 to 1960).

Need for Quantity Storage

It is understandable that this growth pattern would result in some supply and demand or distribution problems. This would be true to some extent if the demand pattern of the industry were non-seasonal. However, the very rapid growth, coupled with the fact that the industry has consistently operated under a somewhat adverse winter to summer volume ratio, makes the supply and demand or distribution problems more acute. About 67 per cent of the product is sold during the winter months of September through March (see Figure 2).

These problems could be solved by the variation of the production rate to meet the seasonal demand or by a more or less uniform production rate with storage of the product during slack seasons for use during the peak seasons.

Obviously, the first method is uneconomical and impractical when considered in conjunction with the over-all features of the LP-Gas industry. For many years, aboveground steel storage tanks operating at atmospheric temperature provided a practical solution to the problem of off-season storage. However, the rapid growth of the industry

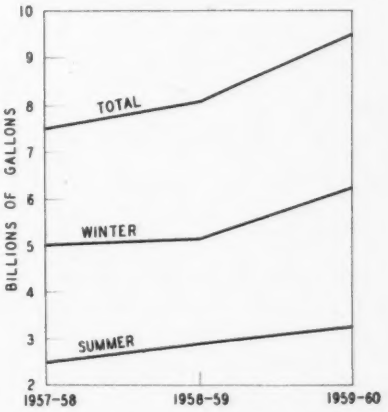


Figure 2. Seasonal demand pattern of LP-Gas. The winter months are September through March.

Presented by Mr. Dyer at the 65th NFPA Annual Meeting, Detroit, Michigan, May 15-19, 1961.

The two principal industries (...) exposed dwellings were also destroyed. Details of the fire and its economic effects on the community of 6,000 are being investigated and will be reported in a future issue of the QUARTERLY.

Sun Oil Company

Photo 1. This 16,800,000-gallon-capacity underground LP-Gas storage cavern was hewn out of solid granite. The 2,244,000 cubic feet of storage space would correspond to a storage capacity represented by about 560 30,000-gallon aboveground pressure containers.

in the late 1940's and the proportionate increase in storage requirements presented very severe economic problems. During this time it became increasingly evident that if the LP-Gas industry were to hold its own in the competitive field of energy fuels, lower cost methods of storage would be required.

In considering various possible methods of accomplishing this, underground storage was, of course, carefully considered. A patent on underground storage methods was issued in Germany in December 1916. The patent covers the storage of petroleum and related hydrocarbons in underground cavities hollowed out in strata which are impervious, homogeneous, and free of cracks as are, for instance, rock salt and potash salts. The original purpose of the method covered by this patent was to make possible the storage of large volumes of mineral oils and liquid hydrocarbons to protect them from external attack and fire hazards.

In considering the possible methods of meeting the problem of seasonal storage of LP-Gas, the apparent fire safety feature of underground storage was, of course, a very important consideration. This feature, plus the apparent over-all economics, made it appear the practical and logical solution to the seasonal storage problem.

Salt vs. Rock Caverns

There are two basic concepts or methods for accomplishing underground or cavern storage of liquefied petroleum gas and similar products in a safe, eco-

nomical manner. Both of these have now been widely used in this country with excellent experience. One method is the storage in a cavity which is dissolved out of a salt formation; the other is storage in a cavern formed by conventional mining procedures in a suitable, insoluble rock formation such as shale, chalk, or granite (see Photo 1). The first cavern in a salt formation in the United States was constructed in 1949. In 1950, the first mined cavern was constructed in a shale formation. In 1960, approximately 2.5 billion gallons of underground storage capacity were available for use (see Figure 3). Roughly 8 per cent of this capacity is in caverns mined from suitable rock formations, and approximately 92 per cent has been dissolved in salt formations.

One of the reasons the largest percentage of this storage has been developed in salt formations is the fact that the cost of mined storage is some 2 to 10 times the cost of storage developed in salt. However, in some areas, suitable salt formations are not available, and mined storage is economically feasible. This is borne out by the fact that 23 mined caverns have been constructed in the United States within the past ten years.

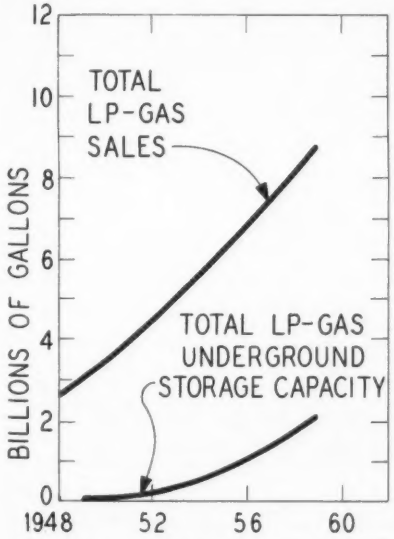


Figure 3. Relationship of underground storage to sales of LP-Gas in the United States.

Safety Standards

The liquefied petroleum gas industry was vitally concerned that these storage facilities be developed in a manner that would result in safe installations. It became apparent in 1952 that some basic and fundamental guideposts should be provided to insure the development of safe underground storage facilities. It was recognized that since the geologic formation and other related factors would vary considerably for each facility, such standards or guideposts would have to be of a general nature. With this in mind and because of member company experience in the new activity, the Natural Gasoline Association of America developed certain basic safety standards for the construction, testing, and equipping of these underground LP-Gas storage facilities. These standards were first published in 1952 and amended in March 1954.*

Since the basic container for the product in an underground storage facility is the geologic formation, the first step in determining whether underground storage is feasible in a given area is always a preliminary study of all the available literature and records covering geologic formations in the area under consideration.

If the preliminary survey shows that necessary formations are likely to exist in the area under consideration, the specific locality is then generally evalu-

*NGAA Tentative Standards for the Underground Storage of LP-Gas, available from National Gasoline Association of America, 422 Kennedy Building, Tulsa, Oklahoma.

ated by drilling (and testing) a core hole. Depending upon the formation involved, a pattern of core holes may then be drilled to prove the extent of the formation. Figure 4 shows the details of apparatus developed specifically for pressure testing these core holes.

In the development of underground storage, the use of salt formations has predominated. Figure 5 shows the areas in the United States in which there are salt domes or salt beds which are suitable for the development of underground storage facilities. Note that it also shows some areas in which salt beds exist but in which the thickness and lateral extent are unknown.

Rock salt occurs in various parts of the world, in sedimentary beds and in domes. The sedimentary beds have been undisturbed since deposition. These beds vary in thickness from a few feet to several hundred feet. A typical salt formation has several layers of salt separated by insoluble layers of shale and anhydrite. The depth below the surface varies from a surface outcrop condition to a depth of several thousand feet.

Salt domes occur in various parts of the world, but the extent of dome formations is much more limited than that of the sedimentary beds. These domes have been formed by being extruded up-

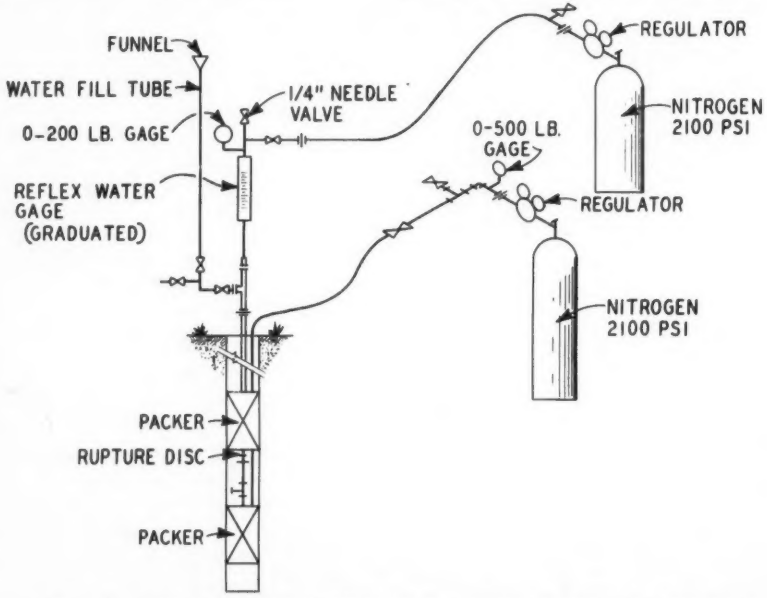


Figure 4. Schematic drawing of equipment to determine permeability of the underground formation. Two expandable rubber packers are placed in a core hole. A perforated pipe in the space between the packers is connected by a water pipe to the water fill tube, reflex water gage, and a nitrogen gas cylinder (upper cylinder in diagram). The lower nitrogen cylinder discharges into the upper packer which is connected by a nitrogen line to the lower packer.

In operation, the rubber packers are inflated with nitrogen, water is introduced through a fill tube until it rises to the top of the scale on the reflex water gage, at which time the valves in the water fill tube are closed. Pressure from the upper nitrogen cylinder is then placed on the water in the reflex water gage forcing water into the formation. The rate at which the water level in the gage drops is a measure of permeability.

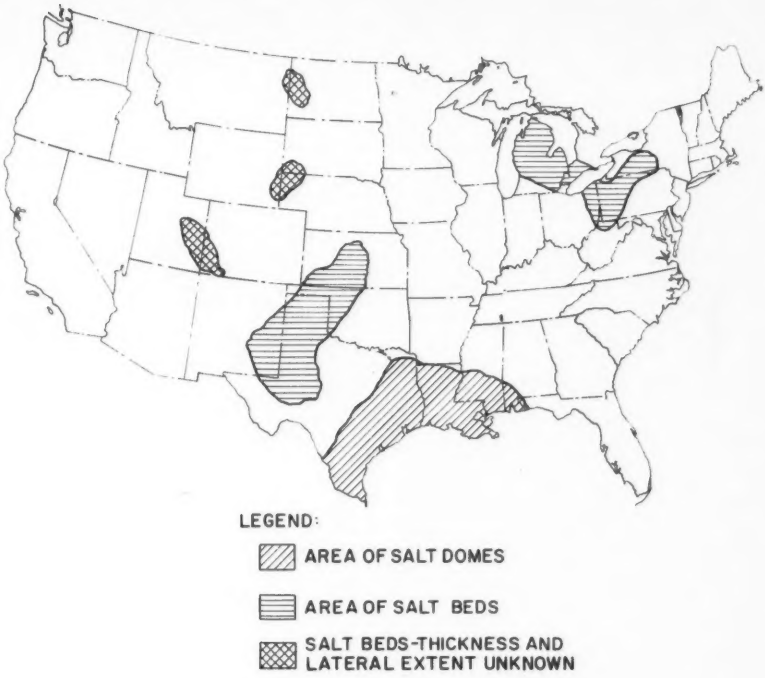


Figure 5. Locations of salt formations in United States.

ward through the overlaying formations with a source of supply being a sedimentary bed at extreme depth. The insoluble stringers found in the sedimentary beds previously discussed are not found in the domes. However, a fine anhydrite sand is dispersed through the salt dome body.

The NGAA Tentative Standards for the Underground Storage of LP-Gas specify a minimum depth of 350 feet for the storage of LP-Gas in salt. Economics and engineering practicality limit the maximum depth to approximately 4,000 feet. From a structural stability standpoint, there is also a depth limitation due to the plastic flow of the salt at great depths. This limit may be somewhat in excess of 4,000 feet.

Salt Cavern Drilling

In drilling a well, casing is set at the top of the cavern and cemented to the surface. Two concentric tubing strings are placed inside the cemented casing for the washing operation. The protective tubing string is used for protecting the cavern roof and regulating the portion of the salt section being washed out at any given time (see Figure 6).

The cavern is then formed by dissolving the salt (by injecting fresh water into the inside tubing string). The resulting brine solution travels upward in the annulus between the tubing and the adjacent concentric tubing and is discharged from the well. The shape of the cavity is controlled by reversal of this flow and by varying the wash rate.

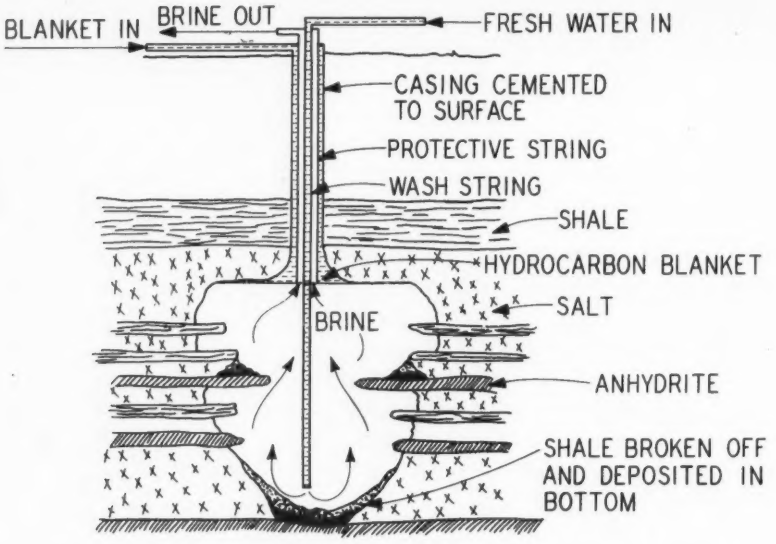


Figure 6. Cross section showing method of washing typical storage cavity in a salt bed.

In sedimentary salt beds, several salt sections can be utilized for the development of the storage cavern. The cavern is located immediately below an insoluble stringer of shale or anhydrite if it appears to offer structural stability to serve as the roof of the cavern. The maximum volume that can be developed in one section is limited by the thickness of the salt section and the massiveness of the insoluble stringer serving as the roof. Of course, there is a maximum diameter beyond which the cavern roof is not stable.

The mechanics of developing caverns in salt domes are essentially the same as those in sedimentary beds. However, there are certain features, particularly cavern shape and maximum capacity, that are different. The massive character of the rock salt makes it possible and desirable to use the salt itself as the cavern roof. The shape of the cavern is then controlled by the washing operation, and the desirable shape with an arch roof and essentially cylindrical body can be obtained (see Figure 7).

As a necessary adjunct to the development of underground storage, a system has been developed for determining the size and shape of underground cavities. The method consists of a sonar-type instrument in which a sound signal is transmitted horizontally with a re-

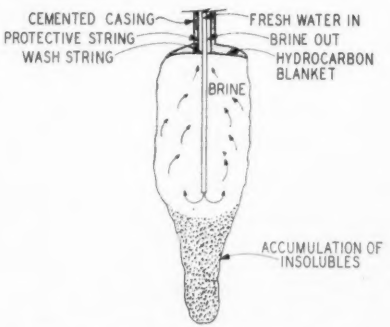
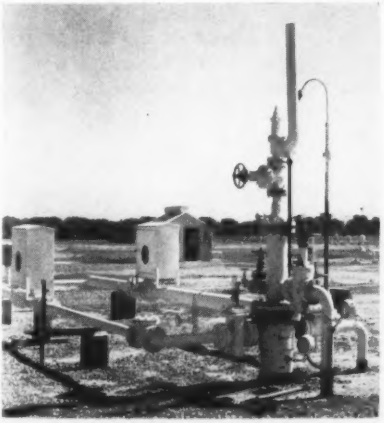


Figure 7. Cross section of a typical storage cavity in a salt dome.

flected signal received by the instrument. By measuring the elapsed time interval between transmitting and receiving the signal it is possible to determine the radius of the cavern at any desired point. The usual procedure consists of determining the cross-sectional area of the cavern in a horizontal plane at predetermined levels. From these area determinations it is possible to calculate with reasonable accuracy the volume of the cavern (see Photo 3).

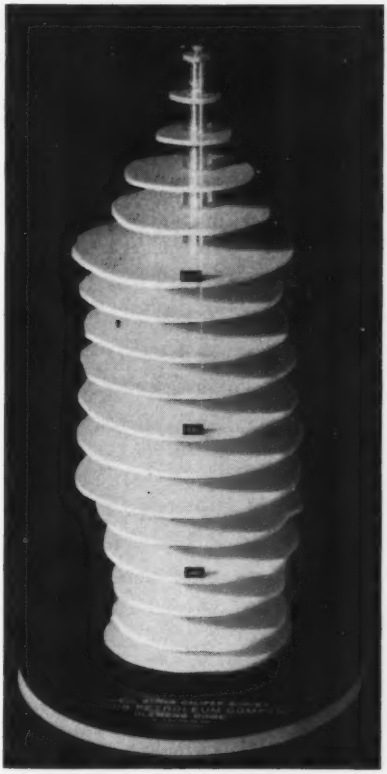
Salt Cavern Operation

Once the cavern has been developed or formed to the desired volume, the tubing used in the washing operation is generally removed and one tubing string for brine injection and removal is run to near the bottom of the cavity (see Figure 8). Appropriate oil-field-type well-head equipment is then installed on the surface (see Photo 2). This well head is equipped with safety relief valves, pressure gages, necessary shut-off valves, etc. The safety relief valve is provided to guard against overpressuring the cavern due to inadvertent overfilling. Obviously, relieving capacity for fire exposure is no problem since the container cannot be subjected to fire.



Phillips Petroleum Company

Photo 2. Salt cavity well head equipment.



Phillips Petroleum Company

Photo 3. Model of underground cavity obtained by use of a sonar-type instrument to determine cross-sectional area at predetermined levels.

The product is removed by water (or brine) displacement. Brine is commonly used for product removal displacement unless it is desired to increase the volume of the cavern while it is in use. Other removal methods, such as pumping, are feasible. LP-Gas underground storage facilities (in salt formations) require very little maintenance. However, there have been cases where it has been necessary to remove the tubing string to repair damage that has

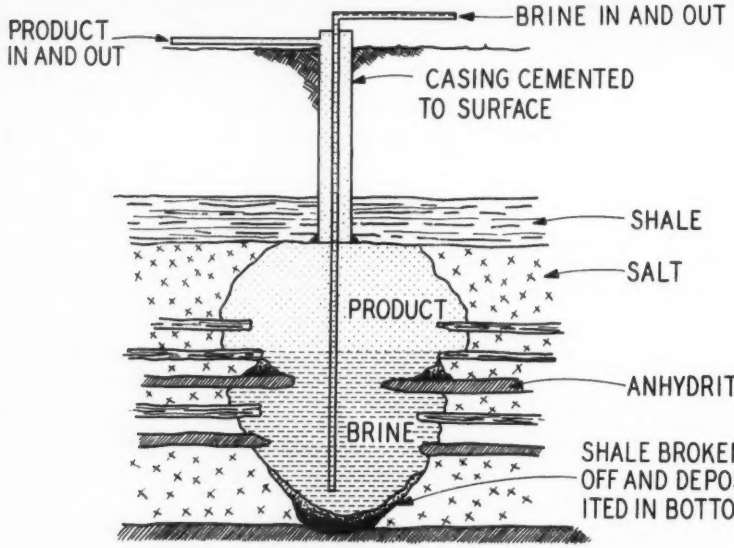


Figure 8. Cross section of a typical storage cavity in a salt bed.

resulted from the insoluble anhydrite stringers falling to the bottom of the cavern, etc. This type of maintenance is performed with conventional oil well servicing equipment and safety procedures. Experience has shown that it can be accomplished with a very high level of safety.

Cavern Mining

In those areas where a suitable salt formation does not exist, it is often economically feasible to develop mined storage in a suitable formation. The NGAA Tentative Standards specify that the maximum operating pressure for underground mined storage shall not exceed 1 pound per square inch gage (psig) per foot of overburden. That is, if the cavern ceiling is 200 feet below the surface, the maximum pressure would not exceed 200 psig. In addition, of course, the rock must be structurally strong, relatively homogeneous, unfractured, inert, and impervious to LP-Gas. Formations which will satisfy these requirements include shale, siltstone, chalk, limestone, and granite. Figure 9 shows the approximate area limits of such formations in the United States. In developing mined caverns, once the preliminary geologic and core drilling surveys have been completed, a shaft is drilled to the required depth. The shaft diameter is as small as possible, commonly 42 inches. A space is then excavated by hand in the bottom of the shaft. As soon as this space is adequate to accommodate several crews, mining is started off in different directions through drifts which are finally expanded into a honeycomb type structure with chambers approximately 20 to 40 feet high separated by massive pillars of rock left in place to support the cavern structurally (see Photo 1).

Techniques have been developed to disassemble bulldozers and loading equipment, lower the parts through the shaft, and reassemble the equipment for use in the cavern. This has proved to

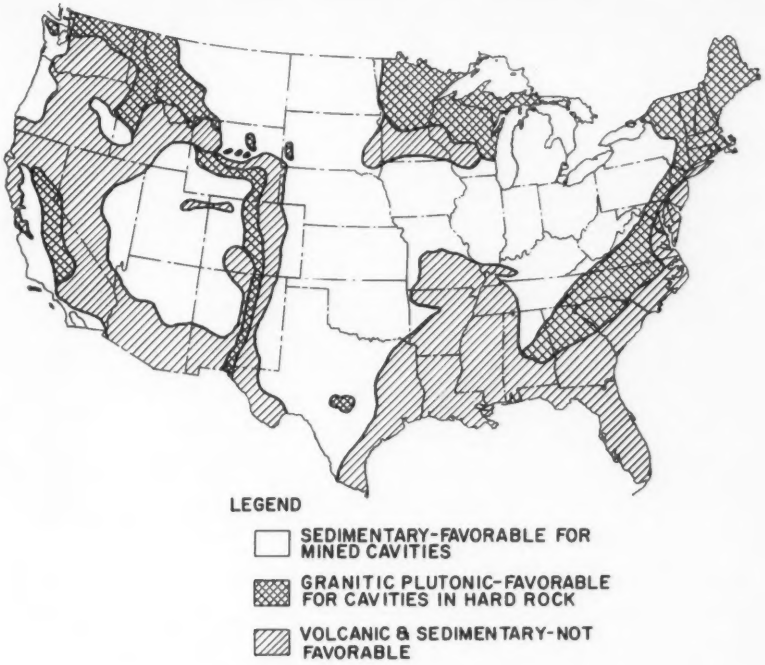

LEGEND
SEDIMENTARY-FAVORABLE FOR MINED CAVITIES
GRANITIC PLUTONIC-FAVORABLE FOR CAVITIES IN HARD ROCK
VOLCANIC & SEDIMENTARY-NOT FAVORABLE

Figure 9. Potentialities for mined storage in the United States.

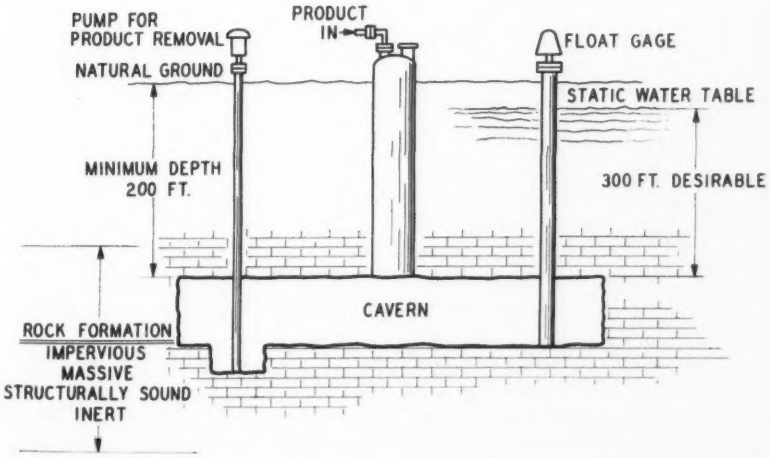


Figure 10. Cross section of a typical mined LP-Gas storage cavern. A honeycomb of caverns extends horizontally in many directions from the central mine shaft.

Tuloma Gas Products Company and Sinclair Oil Company

Photo 4. Surface facilities for mined underground LP-Gas storage facilities.

be the most economical type of mining operation.

The drilled shaft is, of course, lined with a steel liner cemented in place. Liners are also cemented in ventilation holes, which were drilled in the mining operations. In some cases, the vents later serve as fill line connections or product removal wells.

Figure 10 is a cross section of a mined LP-Gas storage facility showing the honeycomb arrangement of the cavern itself and the product removal equipment, gaging equipment, etc., installed in the shaft and ventilation wells.

After mining operations are completed and most of the mechanical equipment is installed, an air test is applied to the cavern to check for leaks.

Deep well type pumps are the common method of removing product from these caverns. It is, of course, necessary to design into the cavern adequate methods for safely removing the deep well pumping equipment for periodic maintenance and servicing. In most cases the pumps are set in pump wells (casing) extending to the bottom of the cavern. When it is necessary to service the pump, the pump well is flooded with water (to form a water seal), after which the pump can be removed quite safely. Photo 4 shows typical surface facilities for a mined underground storage cavern.

Safety of Underground Storage

It is readily apparent that the over-all concept of underground storage of liquefied petroleum gas and related or similar products provides a very high level of safety. The basic container itself is underground, and, therefore, there is no possibility of its being exposed to fire. The aboveground equipment involved is generally comparable to that involved with any LP-Gas storage container. The piping, valves, and fittings, of course, must be of adequate strength and properly installed to insure a safe installation. Hydrostatic relief valves

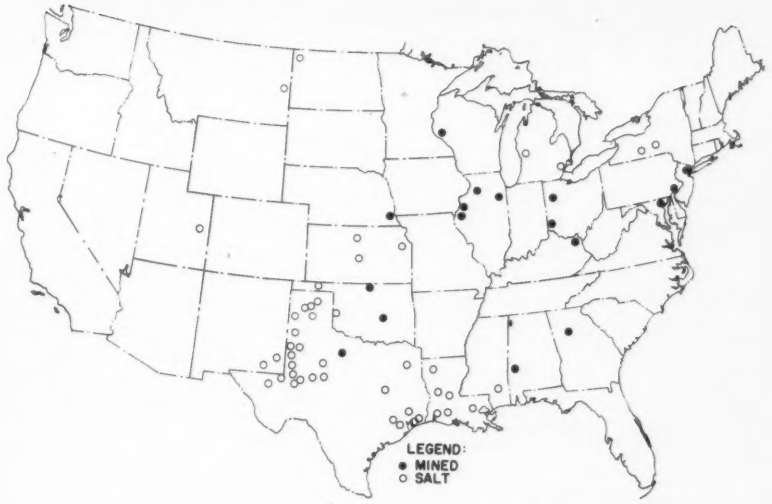


Figure 11. Locations of mined and salt cavern facilities in the United States.

must be incorporated as necessary. With these proper engineering and design considerations and with the proper selection and development of the geologic formation, the storage facility provides a very high level of safety. The experience of the industry with this storage method bears this out.

Figure 11 shows the locations of this type of storage facility in use today in the United States. There are 250 caverns which have been dissolved in salt formations and 23 which have been mined from various suitable rock formations.

Underground Storage of Natural Gas

A related underground storage development, although varying somewhat in detail, is the underground storage of natural gas. Mined caverns and caverns dissolved in salt formations are not used in the underground storage of natural gas.

One method of underground storage of natural gas, which has proved adaptable in some localities, is the repressuring of abandoned underground gas fields. Unfortunately, these fields are not available in many areas where underground storage of natural gas is desired.

Another method involves compressing the gas and directing it underground into water-bearing strata known as aquifers. This method must be devel-

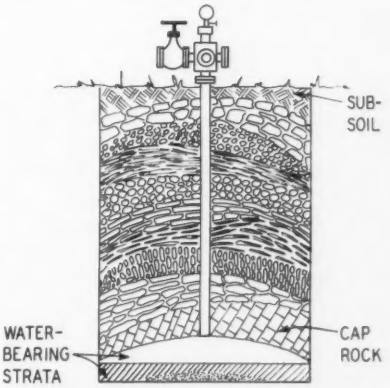


Figure 12. Cross section of water-bearing strata known as an aquifer. Natural gas can be stored in aquifers.

oped in structural formations which meet the following three basic requirements for aquifer storage:

(1) The presence of the kind of structure found in a natural oil or gas field, that is, a stratum in the configuration of a dome which can act as a trap for the gas,

(2) A formation within the domelike structure which has adequate porosity and permeability to retain the injected gas and to deliver it according to usage requirements,

(3) A protective cap rock above the storage zone to prevent upward migration or loss of the stored gas.

Figure 12 shows a typical cross section of an aquifer. Compressed gas is injected into the water-bearing strata displacing the water downward. Injection of the compressed gas may be continued until the level of the water nears the limits of the closure. Observation wells are used to determine when this point is reached. The gas is removed by a combination of the pressure head of the water in the strata and the injection of additional water.

The safety aspects of underground storage of natural gas are similar to those discussed for LP-Gas and related products. For instance, there is no possibility of fire exposure to the container. Also, the aboveground equipment design incorporates the latest safety devices.

An Architect Speaks on Fire Protection

By William A. Halsey

Bastille Halsey Associates

EDITOR'S NOTE: Mr. Halsey was asked to present an architect's point of view on fire protection engineering. His paper, as published here, is essentially as presented at the NFPA Annual Meeting held in Detroit, Michigan, May 15–19, 1961. Mr. Frank Gage, a fire protection engineering consultant, accepted an invitation to anyone in the audience to comment on Mr. Halsey's address. Mr. Gage's comments are also published here. His remarks were necessarily brief and could not cover all points in Mr. Halsey's paper deserving comment.

As an architect, I know and appreciate many of the problems of the fire protection engineer. There is complete agreement on many points including the need for installing fire protective devices, particularly sprinkler systems. There is also agreement with most of the various fire protection engineering standards of the National Fire Protection Association. This agreement exists because architects and fire protection engineers have a common objective: the creation of buildings and space that people may use in a safe manner.

There is this agreement; yet in the buildings I, as one representative of the architectural profession, have designed, you will not find sprinklers. You will not find many of the items of construction, the materials, or the application of the safety standards that you recommend. Why not?

Sprinklers Look Awful

Consider sprinklers. The first thing architects are always faced with is that, esthetically, sprinklers are the most awful looking things ever seen in a building. Usually, a sprinkler system runs its piping exposed. The heads themselves are unattractive, and the pipe collects dirt and dust. The system interferes with proper lighting. It interferes with good color controls. It interferes with anything you wish to do in the over-all volume of the building.

The clean lines and crisp materials of today's architecture are completely destroyed by this myriad of sprinkler piping, unimaginatively placed, reduced in size here, there, and elsewhere, offset, teed, capped, plugged, valved, and what have you — all to solve the basic engineering problems without the least concept of esthetics.

Sprinklers Are Inflexible

The second reason sprinklers are rarely used in my buildings is that they limit the flexibility of rearrangement which is so necessary in a changing and dynamic industrial building. For example, a partition must be relocated. This ordinarily is a relatively simple and inexpensive matter. But where there is a sprinkler system, it becomes an expensive and complex affair. The original piping must be replaced by larger pipes, and the whole system must be relaid.

Sprinkler Installers Don't Cooperate

The third reason we rarely use sprinklers in our buildings is that we have found that most sprinkler subcontractors are not cooperative. Even though we recommend the more expensive method of concealing sprinklers above construction, of drilling holes through beams to make them fit, and of laying out the entire system, when construction actually begins and a subcontractor

is selected, we inevitably find that the sprinkler subcontractor, operating with very little profit, has organized himself to precut all of his pipe and to prelabel all of his fittings. Thus the system comes to the project prefabricated just as it is to be installed, and that is it.

Insurance Authorities Don't Cooperate

There is very little cooperation from the various insuring authorities. Rating bureaus will not consider our drawings in any thorough manner until after the building is under construction. Again and again, they will wish to make many changes. After sprinkler layouts have been reviewed by the various contractors, they are changed with the resulting extras added to the owner's cost. This does not help relations between client and architect.

Criticisms of Fire Protection Engineers

It is our experience also that, in the areas in which we specialize, there are few if any consulting engineers qualified for sprinkler work. To the best of my knowledge, the fire protection engineer has not made himself available to the architect. The fire protection adviser, as we usually know him, is some draftsman in the plumbing department of our general mechanical engineer, and he has as his source of reference, NFPA Standard No. 13, his sprinkler bible. This is the end all of fire protection work — a secondhand plumber!

This then, is the basis for the various layouts, and, for the most part, they will function as far as providing adequate service. In some cases, though, the design is overdone, and in many cases, drawings are underdone. As a result, my office, for one, now writes a performance type specification and requires that the engineering be done by the contractor. This method of operation is not the best from the point of view of the client since it results in the contractor doing his engineering to meet the minimum requirements and not necessarily to provide the best possible protection.

A fire protection engineer has never come into my office to explain or to sell his services for a project. There has never been a fire protection engineer in my office who did more than to lay out a sprinkler system. A man has never been available to us who could integrate and define the advantages of fire protective construction and design, of local hose cabinets, of fire exits, of fire-safe building materials, as well as sprinkler systems. For that matter, no engineer has ever suggested to me which type of sprinkler system or which type of sprinkler would be best to use in this, that, or the other area.

Case of the Disapproved Drawings

A small building of approximately 40,000 square feet was designed and built to house the maintenance department of one of the large eastern universities. It was decided, with agreement by the head of the maintenance department, that as this university was self-insured, fire protection should be built in wherever possible. The building in question housed the following functions:

1. The main office for administration of all maintenance activities
2. Their central store and stock room
3. The central plumbing, sheet metal, and electrical shops
4. The central carpentry shop
5. The central furniture repair shop
6. The upholstering shop
7. The paint shop.

Thus, the building would house a diversified group of operations and was more typical of a small manufacturing plant than a university building. The

owners were urged by the architect to install sprinklers in all areas and cautioned that if there was to be any curtailment of sprinkler areas, sprinklers should be omitted only from the office wing. Although complete sprinkler protection was recommended, the owners felt it was not necessary (a fire protection engineer had never really educated them either). Therefore, sprinklers were installed only in the paint, furniture, and wood-working areas. They were designed for high hazard type occupancy. Fire walls and fire doors were placed around each of these areas, with these fire walls extending through the roof.

A sprinkler contract was let. It was a performance specification type, where the sprinkler subcontractor was informed by the drawings where the main valves were to be located and the general description of this system given, but no layout of piping was made.

Shop drawings were received by the architect for approval. In the review of the shop drawings, several errors were noted and corrected. One of the corrections involved the inspector's test station penetrating through a glazed wall. Corrected drawings were resubmitted and approved. Later, with the job under construction, inspection of the sprinkler installation revealed that the entire installation had been installed according to the disapproved shop drawing!

Clearly, this was a case of a faulty subcontractor's operation and he should have corrected the errors without question. However, arguments lasted for some six to eight months before any change was made, and then only upon payment of a small portion of the cost by the owner. The sprinkler subcontractor claimed that his layout was approved by insurance authorities before it had been submitted to the architect, and, therefore, the architect had no right to make changes. The architect contended that, under the performance specification requirements, submission of a shop drawing must be made to the architect for approval and that any changes desired should be made. If a reapproval was necessary by insurance authorities, then this should have been obtained. Ultimately some corrective actions were taken.

Case of the Ungalvanized Pipe

On another recent project, the sprinkler system, including the inspector's test head, was installed using ordinary pipe. During the course of the job, several letters were written by the architect requesting compliance with the specification requirement that the pipe be galvanized. But nothing was done, and severe staining subsequently occurred on the outside of the building. It is a permanent rusty water stain. To remove this stain the entire face of the building, 30 feet high and 20 feet wide, would have to be replaced because of the homogeneity of the material. It was decided to accept the credit from the general contractor for this damage, and the building stands today, new but stained.

Fire Protection's Responsibility

It is this kind of field experience that makes us think twice about the use of sprinklers. How can this shortcoming and other areas of misunderstanding between fire protection engineers and architects be cleared up? Here are one architect's suggestions:

1. The National Fire Protection Association should do much more in the way of recognizing, awarding, and designating fire protection consulting engineers. All publicity possible should be given to their existence and the tremendously helpful work they

perform to assist architects, engineers, and contractors.

2. The NFPA should undertake an investigation with a panel of architects to determine better design and methods of installing sprinklers for a more esthetic harmony with building design and expression.

3. Top authorities in the fire protection field should present lectures on the various aspects of fire protection to architectural students. From these lectures the young architect will become aware of why, where, and how best to use fire protective devices, equipment, and the fire protection engineers.

A Fire Protection Engineer Responds to Mr. Halsey

By Frank H. Gage, President

Gage-Babcock and Associates, Inc., Fire Protection Engineering Consultants

In response to an invitation to comment on Mr. Halsey's address, Mr. Gage made the following extemporaneous remarks from the floor:

Nine years ago, when I became a fire protection engineering consultant, it was fully expected that most of my work would be with architects. Since that date, I may have called on five hundred or more architectural firms. Many of the same arguments that Mr. Halsey has used about planning fire protection in buildings and getting fire protection incorporated in the designs during the planning phase were used. Yet, despite these efforts, at the most, one per cent of the fees we have earned in the fire protection field have come from architects. In many of the few instances in which we have done work with architects, the architects have agreed to employ us only when the owner has asked them to do so and has agreed to pay the extra fee.

The entire fire protection industry has a job to do in promoting the importance of fire protection engineering, but I also throw the challenge back to Mr. Halsey for, in discussing this problem with many men in the American Institute of Architects, including its president and many chapter presidents, I have found very little favorable reaction to the fire protection engineering field and almost no interest in engaging the services of consultants from this field.

I have asked members of the American Institute of Architects why they did not invite fire protection engineers to speak at national or local AIA meetings. One program manager told me: "We are interested in aesthetics, design, and structural aspects. No one would be interested in listening to such a program item." It is true that the fire protection engineer must assume some of the blame for the lack of appreciation by architects of the services that can be rendered by the fire protection consultant. But I think, also, that men such as Mr. Halsey, who have become interested in this field, have a job of education to do in their own profession.

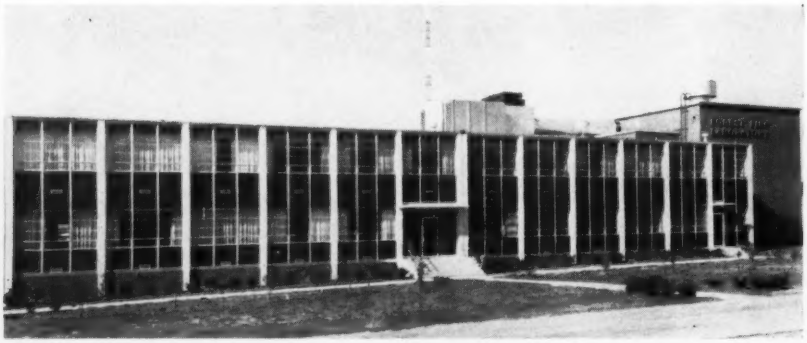
Some time ago a letter went out from a federal agency stating that henceforth all architect-engineer firms doing work for this agency were to give as much recognition to fire protection engineering as was given to mechanical, construction, and electrical engineering.

All of these architect-engineer firms were required to show proof of having a qualified fire protection engineer on their staff, or they were to engage the services of such an engineer. The agency listed the qualifications for membership in the Society of Fire Protection Engineers as those that the architect's fire protection engineer must meet. The reaction of architects was not too favorable. Many complained in writing about this requirement. To date, it has never been enforced. This particular agency constructs annually buildings and structures worth more than one billion dollars, but the architects who are designing these buildings and structures have not called in fire protection engineers for consultation even though this agency has been willing to pay slightly higher fees in order to cover the cost of such consultation services.

The responsibility for this situation rests with the fire protection profession as well as with the architect. It can only be corrected by the cooperative effort of the fire protection profession and architects.

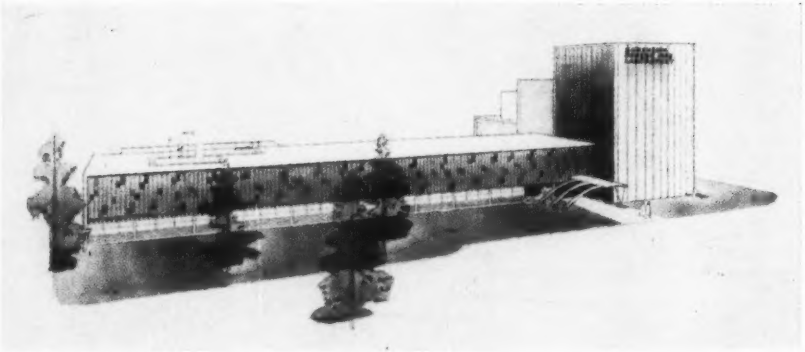
Forest Fire Laboratories

Forest fire laboratories have been provided at two of the Experiment Stations of the Forest Service, U. S. Department of Agriculture. The buildings are shown in accompanying illustrations. Facilities include a tower section in which fires can be built under controlled air temperature, atmospheric pressure, and relative humidity. Wind tunnels are provided for speeds up to 50 miles per hour. Other facilities include laboratories for fuels, physics, chemistry, and meteorology, with service facilities, library, and outside ground space.



U. S. Forest Service

The first forest fire laboratory in the world at the Southeastern Forest Experiment Station, located near Macon, Georgia.



U. S. Forest Service

The forest fire laboratory at the Intermountain Forest and Range Experiment Station at Missoula, Montana, dedicated in September 1960.

The Madrid Eyeglass Factory Fire

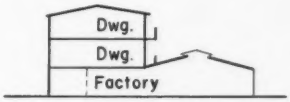
By F. Antonio Salas, Fire Protection Service of Madrid, and Norman R. Wypruk, Royal-Globe Insurance Companies

Just before quitting time on the evening of February 22, 1961, a spark fell from a circular saw in The Madrid Spectacle Frame Co. and landed among nitrocellulose dust and chips on the floor. The flash fire that followed trapped and killed 23 of the workers in the rear part of the small, one-exit building. Five other persons were burned while escaping, one of whom subsequently died. This story of 24 deaths and 4 injuries is another illustration of the hazards of nitrocellulose (pyroxylin plastic), and of the death traps created by exitless portions of buildings — lessons that had been learned harshly long ago.

The Building

Originally, the 3-story masonry and reinforced concrete building at 19 Uceda Street in the Puenta de Valecas section of Madrid had been a three-family dwelling, one family occupying each floor, but subsequently the first floor was converted to use as a factory. Later, when the factory required additional space, the open rear courtyard was roofed over with tile-covered concrete slabs on protected steel supports (see Figure 1). In the center of the new rear roof there was a skylight with wired-glass in metal frames. When the original rear exit into the courtyard was eliminated by this construction, no substitute was provided (see Figure 2). Thus after the extension, the 25-foot by 65-foot fire-resistive building had only one ground floor exit — the door to Uceda Street in the front of the building. The front window was barred and was also covered by wire mesh.

The upper floors were still used as living quarters for two large families. The only exit from these upper floors



A – A

Figure 1. Section A-A of building taken as shown in Figure 2.

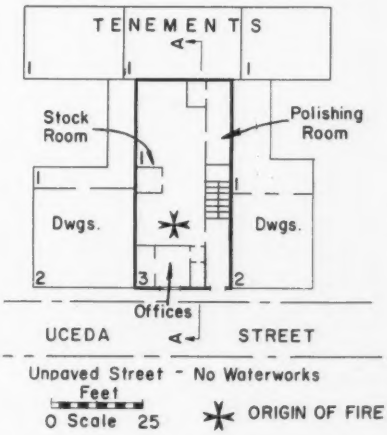


Figure 2. Plan view of ground floor.

Mr. Salas is a Zone Chief of the Madrid Fire Department. Mr. Wypruk, who is in the Montreal Special Risk Department of the Royal-Globe Insurance Companies, was in Madrid at the time of the fire. Mr. William Pierce, Boston office of The Employers' Group, translated the Spanish reports.

Norman R. Wypruk

On February 21, 1961, 24 workers in this Madrid, Spain, eyeglass factory lost their lives. All except one of the fatalities occurred because a fire, involving pyroxylin plastic, prevented the victims, working in the rear, from reaching the front exit shown in the photo. This was the only exit from the building.

was down a concrete stairway past the factory door in the first floor 39-inch-wide passageway and thence to Uceda Street.

The factory area was composed of a front section made up of a small coat room, two storage areas, and an office. Behind the front section was the open factory area with cutting, grinding, and other nitrocellulose working operations. A raw-stock room was located in this area. On one side of the open factory area was a polishing room, and off that, another small storage room. There were no automatic sprinklers.

The Operation

This factory manufactured sunglasses, eyeglass frames, and novelties. The electrical equipment included saws, grinders, buffing wheels, and other appliances not specially designed for use in hazardous locations. A small refuse-fired stove was located in the work area. The stock room contained about 2,000 pounds of nitrocellulose sheeting. These sheets were not separated into compartments of 250 pounds capacity as recommended by Standard for the Storage, Handling, and Use of Pyroxylin Plastics in Factories Making Articles Therefrom (NFPA No. 42).

The Fire

Several times during the previous operation of this plant, sparks from the sawing operation had dropped into small piles of dust or chips. Previously they had been confined and extinguished. At 6:30 P.M., on February 22, as the factory was about to close for the day, there was a large accumulation of dust and chips on the floor. A male employee was cutting a piece of the plastic on the saw when a burning chip jumped from the saw to the floor. The scrap ignited and flames quickly spread to the adjacent stock room. The blast of heat and smoke was practically instantaneous. The heat and dense smoke pushed against the concrete ceiling and the wired-glass skylight. Eventually, the glass melted, allowing the heat and smoke to start escaping, but by then the damage had been done.

The People

Working in the factory at the time of the fire were 32 employees. These were mostly young girls between 16 and 22 years of age. When the spark hit the floor, there was little time for anyone to do anything more than react instantaneously and instinctively. The 23 persons who found themselves cut off from the only exit pushed into the polishing room. Four crowded further into the adjacent storage room and several found a sheet of plywood, which they pulled over themselves in a vain attempt to survive. They did not succeed, for the clouds of smoke contained, among other things, highly toxic oxides of nitrogen, one of the products of burning nitrocellulose. They died without a burn on them or their clothes — trapped for want of any way out.

The nine persons on the exit side of the fire fared somewhat better. Three men and three girls were working in the factory. Another girl was sweeping in the hall just outside the factory door, and a man and girl were in the company office. The explosively spreading fire burned the three men as they rushed for the exit. One was so severely burned that he subsequently died from the effects. Ahead of them, the three girls, guided by the sweeper, fled out of the exit. Two of these girls were burned. The two office occupants were able to run out the factory door to the hallway without injury.

The family on the second floor was rescued by fire fighters with self-contained breathing apparatus, who led the mother, four children, and grand-

Norman R. Wypruk

The skylight over the 1-story section of the building contained wired glass. Some of the glass panes sagged while others fell out completely. Opening of the skylight in this manner vented the smoke and hot gases before fire fighters arrived.

parents down the stairs as other firemen worked a spray hose line in through the door to the factory. The family on the third floor was also rescued this way. The skylight over the 1-story section had vented the heat and toxic gases by the time fire fighters arrived, making the evacuation by the stairway from upper floors possible.

The Fire Fighting

The fire fighters of the city of Madrid received the alarm by telephone at 6:35 P.M. Three pumpers were dispatched to the scene. These pumpers carried 550 gallons of water each, as this section of the city was not supplied by public fire main. The first arriving pumper stretched a 2.2-inch spray-nozzle-equipped hose in the front door to the factory doorway while other men donned self-contained oxygen breathing apparatus and headed up the stairs to rescue the families located above. The men on the second and third engines laid hoses to the roofs of the buildings on each side of the rear one-story section of the factory. Finding the skylight already melted, they played water through this opening on the fire. They also opened up the roof in one place to get at the fire. Extinguishment was completed within 10 to 12 minutes after fire department arrival. The fire did not spread outside the floor of origin.

The first arriving officer had found the fire a hot, smoky one and called for assistance. It came in the form of four tank trucks, additional men and officers, police, medical, and auxiliary services. An indication of the tremendous heat developed was the melted glass in the skylight. The short duration of the fire and the fire-resistive construction accounted for the lack of structural damage over the area of worst fire exposure.

The Damage

The office equipment and the contents of the factory were destroyed but the door and window trim were only lightly damaged. Smoke damaged the contents on the upper floors.

The Lessons

Fire-resistive building construction by itself does not insure life safety. Without exits and proper control of operational hazards, there can be no life safety. As with the 83 killed in the Bogotá, Colombia, department store fire (see *Fire News*, January 1959), these victims died because there was only a single exit, and that exit was blocked.

The following fire protection weaknesses were listed in the report of the Madrid Fire Department as being responsible for this disaster:

1. The lack of an emergency exit other than the main factory exit.

2. The placement of the circular saw in the center of the work area rather than in a properly isolated location.

3. The lack of any vent in the improperly located pyroxylin storage area.

Norman R. Wypruk

Fire damage to the fire-resistive building was confined primarily to wooden door and window frames. Wooden workbenches and storage units were severely damaged.

4. The lack of fire safety precautions in pyroxylin processing.

5. The limited space in the plant.

These items would have been properly handled had the NFPA Standard No. 42 been enforced in Madrid. This Standard, first drafted in 1921 and revised up to 1936, has stood the test of time. The following paragraphs are a sampling of its recommendations:

15(a). All buildings or portions of buildings used in whole or in part for the fabrication of pyroxylin plastics shall be provided with adequate aisle space and have at least two exits remote from each other.

37(f)1. Each (storage) vault or compartment of a cabinet shall be separately vented to the outer air.

39(b)1. Workrooms of both classes (hazardous and nonhazardous) shall be separated from each other and from rooms used for other manufacturing or storage purposes by fire-resistive partitions as specified in Section 16 of these standards.

48(a). Shavings, chips, turnings, sawdust, edgings, trimmings, and other materials resulting from manufacturing processes shall be kept thoroughly wet in a metal receptacle until removed from premises and shall be safely disposed of at frequent intervals. . . .

48(e). A jet of water shall continually play upon saws, cutters, and similar machines which are likely to heat the pyroxylin plastic to the ignition point by friction or otherwise when they are in use. . . .

14(e). All new and existing buildings shall have all parts of the building used as a factory or for storage equipped with a standard system of automatic sprinklers. . . .

Because of the exceedingly quick burning nature of pyroxylin, the NFPA Standard for the Installation of Sprinkler Systems (NFPA No. 13) calls for sprinklers to be installed in pyroxylin factories on the basis of the extra-hazard schedules outlined therein. If pyroxylin products are to be manufactured, the factory must be located where adequate water supplies are available.

Institutional Fire Protection Is Different

By Rexford Wilson, Fire Record Editor
National Fire Protection Association

Institutions are different from other occupancies in two important respects. When these differences are recognized and the fire protection requirements necessitated by these differences are accepted, nursing homes, hospitals, prisons, and other institutions will be fire-safe places for their occupants.

Why Institutions Are Different

Why are institutions different? They are constructed of the same materials, have the same general shapes, and have people in them as do schools, churches, restaurants, theaters, and most other occupancies, yet they are different. Why?

A church is classified in the NFPA Building Exits Code, as a place of public assembly. So are auditoriums, theaters, and night clubs, to name a few. These buildings are occupied for a relatively short period, and usually the people that assemble are healthy and capable of intelligent action when properly stimulated. In case of fire these people can escape safely if there are adequate exits.

Schools are occupied for part of each weekday by people who are young, healthy, agile, and under a practiced discipline. In case of fire, their safety will depend primarily on safe ways out.

But what of institutions? These buildings, unlike churches and schools, are being used every hour of every day, of every night, weekend, and holiday. Unlike churches and schools, people in these institutions are often not so young, not so agile, and not so normal, and for one or more of these reasons require constant care. Is it going to do any good to place reliance for the life safety of these people primarily on exits?

These then are the two points that make institutions different from other buildings: constant building use and constant patient care.

Constant Building Use

In buildings used constantly, the hazards of fire are greater, due to a greater amount of activity. As one prominent doctor said: "Hospitals are made to be abused, and the hospital staff routinely abuses the building from the day it opens." Since the building is in constant use, not only is the fire hazard greater but each fire can affect the patients. Thus constant building use means constant possibility of fire and patient exposure to fire.

Constant Patient Care

Constant patient care indicates that the patient cannot always be counted on to get himself out. He may be physically or mentally incapable of movement; he may be under restraint; he may be unfamiliar with the exit route; and he may not know the emergency routine.

Fire Protection Requirements

The two factors that make institutions different, constant building use and constant patient care, require a different approach to the four basic

keys to fire protection: built-in protection, inspection, training, and evacuation.

Built-in Protection

The most important part of an institutional fire protection program is built-in protection. What is this built-in protection? It is the protection provided by fire-resistive building construction. It is the protection of ample, properly installed fire and smoke divisions. It is the protection of limitation of combustibles. It is the protection of automatic sprinkler systems, and, in some cases, automatic fire detection systems.

Recommendations on sound built-in protection will be found in the Building Exits Code of the NFPA (No. 101).* Created and amended as necessary by the NFPA Committee on Safety to Life, this nationally recognized Code sets forth the minimum requirements for built-in protection to guard the occupants of institutions, schools, places of assembly, and other buildings from the dangers of fire. None of the fire tragedies of this century, e.g., the Ohio State Penitentiary fire, the Cocoanut Grove Night Club fire, the Effingham Hospital fire, the Warrenton Nursing Home fire, and the Chicago school fire would have been tragedies if these buildings had complied with the life safety recommendations of the Building Exits Code.

Inspection

The second key to institutional fire protection is a vigorous inspection program, not only by the fire department and insuring company on a quarterly, semi-annual, or annual basis but also by members of the institutional staff on a weekly basis in some areas, or on a daily basis in certain other areas.

*Published separately and in the National Fire Codes, Volume III.

Training

The third key in unlocking a successful fire protection program in institutions is the training not only of the staff, but also of the long term patients, and the fire department personnel who will respond. The training, to be successful, is a constant and repetitive job. Each person working for an institution may be the first one on a fire scene. Each must know what is expected of him and how properly to discharge this duty. Fortunately, the cry "Fire" is heard in an institution infrequently, but it can signal one of the most crucial moments in the life of the structure and of the people in it.

Evacuation

The fourth feature of a successful fire protection program for institutions is the evacuation plan. All too often the difference between the term evacuation as it is applied to institutions and as it is applied to other occupanices is not understood. In a fire condition of anything but embryonic proportions in an institution, there is not the time nor the staff to provide proper evacuation for the entire building unless there is also proper built-in protection, purposeful inspection, and effective training of the staff. So, the evacuation program should be a limited one conceived in concert with the built-in protection and made possible by the inspection and training procedures. A successful program makes provision for those in the fire area on one floor to be moved to another fire area on the same floor, or, if necessary, to a fire area on the floor below. Evacuation in a properly safeguarded institution will be necessary only from the immediate fire area.

Fire History in Institutions

Through fire history, the effects of constant building use and constant

Wide World

Nursing Home, Washington, D.C., Feb. 1, 1961, 7 killed. Unsprinklered, combustible construction, patients above second floor. The fire originated in a first-floor closet, spread into a hallway and up a rear stairway. Although doors at floor landings were effective fire barriers, seven of the eight fourth-floor patients lost their lives.

patient care on the four key life safety provisions for institutions can be examined. What was the institutional fire record during the 1950's? This decade experienced 16,500 institutional fires, large and small, in the United States. These fires took the lives of more than 500 persons and destroyed over $27,000,000 worth of property. Sixty-one per cent of these deaths occurred in nursing home fires, 15 per cent in mental institutions, 12 per cent in penal institutions, 11 per cent in hospitals, and 1 per cent in orphanages. The major institutional killer is, then, fire in the nursing home. What does the study of fires tell of the dangers in these buildings?

Nursing Home, Washington, D. C.

On February 1, 1961, in Washington, D. C., the Mount Vernon Nursing Home experienced a fire which was fatal to seven patients ranging in age from 63 to 90 years. Thirty-three other persons were reported as injured. The fire started in a closet for medical supplies on the first floor. From a life safety point of view it is not so important to know why this fire started as it is to understand how it caused loss of life. The fire could have been caused by anything, but the loss of life was caused by a set of physical conditions that are fully understood and could have been permanently corrected before the fire.

The fire was detected by the operator of the home when he discovered smoke coming from over the door to his first floor office. He opened the door and found the hallway filled with smoke and fire. Heat spread up the rear stairway but was reportedly blocked from entering upper floors at each landing by sheet metal-covered wooden doors. It reached the ceiling of the stairway and intensified. The wooden stairs were now burning, adding more heat. Reports indicate that fire broke through the stairway ceiling and burned briefly in the concealed space under the roof before breaking down through the ceiling of the fourth story, killing seven of the eight patients on this floor. One patient had been removed by an attendant at the time of discovery, but the attendant could not return to get anyone else because of smoke and heat.

The speed of a fire like this is incredible. The fourth floor of the Mount Vernon Nursing Home was probably filled with smoke and heat within three to ten minutes of the time the first lick of flame escaped from the closet. What caused the flame is not important; the fact that it ever got out of the closet is.

Examine this fire and see how the four keys to institutional life safety fit.

Would *evacuation* have helped here when the attendant couldn't even return to the fourth floor one minute after he had left? Would any amount of *training* of the fourth floor attendant or the person who discovered the fire have changed the number of victims?

How about *inspection*? A careful inspection might have revealed the one thing that caused this closet fire. Would that have changed the basic danger of this building? Certainly the removal of this cause would have stopped this fire. But the cards had already been dealt and chance was still playing the hand. Any other cause, at any other time, could have resulted in the same deaths by the same route of fire spread.

What about *built-in protection*? What about the Building Exits Code? Would these old folks have died if the Building Exits Code had been in force in the nation's capital? If the Building Exits Code had been adopted in Washington last year, this 4-story building of combustible construction could still have

United Press

Nursing Home, Warrenton, Mo., Feb. 17, 1957, 72 killed. Unsprinklered, combustible construction, open passageways and stairways.

been used as a nursing home only if it had been equipped with a complete automatic sprinkler system and only if the patients were limited to use of the first two floors.

Nursing Home, Warrenton, Mo.

The classic nursing home fire occurred in February 1957 in Warrenton, Missouri, at the Katie Jane Nursing Home.* In 1955 a man acquired some former college buildings and converted them to nursing home use. The main building, the annex, and the connecting passageway were of masonry, wood-joisted construction and comprised one fire area due to the absence of doors in the passageway and building corridors. There were three stairways from the second floor, all open and all discharging into the open first floor.

Bed patients were housed on the second floor so that ambulatory patients would not have to use the stairs. As far as can be determined not one bed patient survived. There were four attendants and five other employees with various household duties who served as nurses' aides when needed. There were possibly 50 Sunday visitors throughout the building, 59 able-bodied persons, in all, ready to help the 149 occupants in case of fire.

Shortly before 2:30 P.M. a 92-year-old patient thought he smelled smoke in the first story of the annex. Although no one heeded his warning, he dressed and went outside. The first story attendant in the annex was upstairs assisting the second story attendant with a patient. At approximately 2:30 P.M., a visitor in the passageway looked into the first story of the annex and saw fire coming from the wood lath and plaster ceiling adjacent to a linen

*For a detailed report see Warrenton, Missouri, Nursing Home Fire, March 1957 *Fire News*.

closet beneath the stairway to the second story.

During the estimated five minutes it took for the visitor to find an employee, for the employee to verify the presence of the fire and to telephone the alarm from the office in the main building, smoke, hot fire gases, and flames had spread so rapidly that the employee, after completing the call, could not re-enter the annex. Eight first floor patients and three from the second floor managed to escape with the help of visitors and attendants during the first five minutes. The other twenty-three patients in the annex were trapped and killed.

As soon as shouts of "Fire" were heard, visitors and attendants in the Main Building did what they could to get the elderly inmates out before smoke and hot fire gases pouring through the open passageway from the annex made the main building untenable. At the most, there was ten minutes' time during which evacuation of the 115 persons in the main building would have been possible. Seventy-two persons died in this building. Only seventy-seven had been removed.

Where was the evacuation system, the inspection, the staff training? There was not time because there was no built-in protection, no smoke divisions, no enclosed interior exits. Again, without sprinklers this combustible building was unsuitable as a nursing home.

Nursing Home, The Dalles, Oreg.

In the Mid-Columbia Nursing Home in Oregon last July, a 60-year-old patient set fire to the clothes in his closet. He shut the closet door and retired to the hall shutting the room door. He wanted to see what would happen. Within a minute, the sprinkler alarm bell began ringing. At first, the supervisory personnel thought it was a test of the system, but a nurse soon saw water coming under the door of the room. The fire had been extinguished by the single sprinkler in the closet and the damage amounted to $35, a far cry from the closet fire in Washington, D. C., and the closet fire in Warrenton, Mo. This is a good example of one of the reasons why the Building Exits Code insists on sprinklers for most types of combustible nursing homes.

Prison, Columbus, Ohio

Prison fires provide interesting challenges to the fire protection engineer. The classic case occurred just before dark on an afternoon in April 1930 when smoke was seen pouring from the roof of the Ohio State Penitentiary in Columbus. A fire in the wooden forms for a new cell block under construction was spreading to the old wooden roof over the otherwise fire-resistive, cell block. In this overcrowded installation, each cell of the six tiers had to be unlocked individually. By the time the decision was made to free the men, the upper two tiers of the six were not approachable. Before the fire could be controlled, 320 prisoners had died and 133 others were seriously injured. Weaknesses in the built-in protection of the prison that were responsible for the 320 deaths included the combustible roof, lack of sprinklers, and the absence of cut-offs between the old cell block and the new.

Reformatory, Wrightsville, Ark.

Another example of a penal institution fire occurred in March 1959 in a boys' reformatory in Wrightsville, Ark.* Twenty-one of the 68 boys that had been locked in the barracks-type dormitory for the night lost their lives when fire broke out in an adjoining section of the one-story combustible building. The caretaker, who normally stayed in the building, was absent due

*For a detailed report, see Large Loss of Life Fires in 1959, July 1960 NFPA QUARTERLY.

International Newsreel

Prison, Columbus, Ohio, April 21, 1930, 320 killed. Unsprinklered, combustible addition, lack of cutoff.

to illness. No substitute had been provided.

Ignition of the combustible fiberboard ceiling by the vent pipe from a stove in the recreation room was the probable cause. The fire was spreading along the ceiling and had gotten into the undivided attic before one of the boys awoke at 3:15 A.M. Kicking out the heavy wire screening on one of the windows he escaped and ran to another building to give the alarm. As the other boys awoke and found the room in which they were caged filled with smoke, they struggled wildly to get out through windows. Twenty-one were trapped by flames, heat, and smoke, before they could escape, only minutes after flames first flickered over the combustible fiberboard surface.

The Board of Trustees subsequently fired the superintendent for failure to provide an adult on duty in the building with keys. It is true that someone with keys might have helped, but here again people were placed in an unsprinklered combustible institution. The Building Exits Code requires sprinklers for combustible penal buildings.

Prison, Thomaston, Me.

Prisons can have built-in protection as the report of an October 1959 fire in Maine State Prison shows. The prison's built-in protection included fire-resistive construction and automatic sprinklers. A fire of suspicious origin started in a corner of the prison print shop after prisoners had locked up the room for the noon meal. Five of six sprinklers in the room operated and extinguished the fire. Damage to paper stock in the room amounted to $8,000.

There was no damage to machinery, no damage to buildings, and no lives were lost.

Hospital, Effingham, Ill.

There is little satisfaction to be taken in the fire protection provided for some of our hospitals. Consider, for example, the St. Anthony Hospital fire at Effingham, Illinois, in April 1949.* Believed to

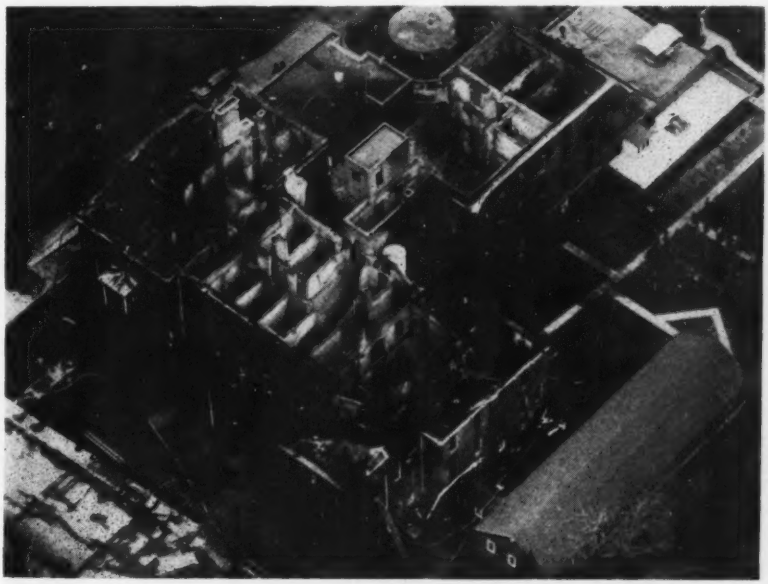
*For a detailed report, see The Tragedy of St. Anthony Hospital, July 1949 NFPA QUARTERLY.

have started in one of three laundry chutes, the fire burned unnoticed until smoke was detected by a third floor attendant. She called the switchboard operator who called the chief engineer, the Sister Superior, and the Effingham Fire Department. The fire had already spread from the chute to the second and third floor corridors upon the arrival of the fire department, and flames broke through the roof a few minutes later. With no smoke barriers in the hallways and with the presence of combustible acoustical tile ceilings, the flames quickly cut off all escape by corridor. Of the 74 dead, only three died on the first floor but 29 died on the second floor and 42 on the third floor.

This combustible building had no built-in features to limit fire spread, such as enclosed stairwells and ducts, no fire doors between building sections, and no automatic sprinkler or detection systems. With the corridors made impassable by the rapidly spreading fire there was no way for occupants to get to the fire escapes and stairways. Once again, with proper built-in protection not provided, there was no time for trained persons to evacuate patients.

Hospital, Minneapolis, Minn.

The need for care in all phases of protection, and particularly in selection and use of interior finish, is emphasized by this December 1956 case. A Christmas tree in the lobby of the fire-resistive Doctors' Hospital in Minneapolis, Minn., ignited from a short circuit in electrical wiring during the evening. The rush of heat from the burning tree ignited wood paneling in the lobby, and fire rushed toward a stair tower that had been designed to be completely enclosed. However, at the time of this fire, the door at the



Acme

Hospital, Effingham, Ill., April 4, 1949, 74 killed. Unsprinklered, combustible construction, unprotected vertical and horizontal openings, combustible interior finish.

United Press

Hospital, Minneapolis, Minn., Dec. 23, 1956, 7 killed. Unsprinklered, combustible interior finish, combustible Christmas decorations.

bottom of the stairs was blocked open as were doors at each upper floor level. Flames poured into the stairway, and a wave of hot searing gases rushed upward. Nurses on each floor sped to close the life-saving doors. Those on the second, fourth, and fifth floors succeeded. The nurse on the third floor tripped and fractured her skull. Heat and the products of combustion pushed into this floor and into the rooms of seven patients who were killed. Fire fighters were forced to use ladders to evacuate twelve other patients during the sleet storm which was in progress.

What happened here? There was part of the built-in protection in fire-resistive construction and enclosure of stairways, but the safety of the occupants had been jeopardized by the combustible paneling in the lobby, by inadequate staff training, as evidenced by the blocked open doors, and by the absence of automatic sprinkler protection which would have had the capability of extinguishing the fire before it spread.

Hospital, Albany, N. Y.

Can hospitals be adequately protected? The first floor pharmacy of a 7-story fire-resistive Albany, N. Y., hospital was the scene of a fire in August 1960. The pharmacy was valued at over $95,000. A stock boy emptied acetone into the sink, and vapors ignited from the flame of a laboratory burner nearby. Heat operated two sprinklers which extinguished the fire. Total damage to the room and its valuable contents was $400.

Conclusion

The responsibility for safe institutional buildings rests in two places. It is urgent that this division of responsibility be recognized so that the institutions of today and tomorrow will provide fire safety for their occupants.

The basic responsibility lies with the operator or administrator of the in-

stitution. He is the one who must see to it that the fire protection needs of his patients are met, just as he sees to it that the best medical help available is on the staff and that the best medical equipment is provided. The secondary responsibility rests with those in the fire protection field. They are looked to for advice and guidance on all phases of institutional fire safety by those in charge of institutions. It is the fire protection engineer's primary responsibility to recommend the built-in protection needed.

This built-in protection can be provided through fire-resistive building construction, ample, properly installed fire and smoke divisions, limitation of combustibles, automatic sprinkler systems, and, in some cases, automatic fire detection systems.

Without built-in protection, the good inspection, training, and evacuation programs are not going to prevent large loss of life in institutions as proved by the fires of the past Built-in protection, in combination with careful fire prevention inspections, effective training sessions, and practiced evacuation plans, will provide sound and sensible life safety for institutions.

Anniversary of London's Tooley Street Fire

June 22, 1961, was the 100th anniversary of the famous Tooley Street Fire in London. In this fire, James Braidwood, Chief Officer of the London Fire Engine Establishment, was killed. After this fire, the British insurance companies turned the operation of the Fire Engine Establishment over to the Metropolitan Board of Works, marking the beginning of London's public fire department. During the anniversary, both the contributions of the insurance companies to the development of public fire departments and James Braidwood's contribution as the first great professional fire officer were recognized. The above is a reproduction of an oil painting from the collection in London of the British Fire Protection Association, through whose courtesy we are able to reproduce it.

Problems of Water Supply

By John W. Cramer, President Elect

American Water Works Association

Every water system is, or should be, designed by fire fighting requirements, not by the needs of domestic, commercial, and industrial users. If in designing new systems or extensions to existing ones, the engineer had only to provide for domestic, lawn watering, and commercial and industrial process needs, public water supply systems would cost only a small fraction of actual expenditures. Of course, no one in the water supply industry designs to the exclusion of fire requirements, nor would want to. Consulting engineers today uniformly design to the standards of the National Board of Fire Underwriters for the particular class of city involved. In fact, where it is possible and economically feasible, most of them are constantly seeking to raise a city from a lower to a higher NBFU class, at least insofar as the water system is concerned. In this part of the water works engineers' job, as in several other parts of it, there are many problems. The NFPA and AWWA can make common cause to solve at least some of them, and to their mutual benefit.

Plant Deficiencies

The water works industry is confronted today with some rather serious plant deficiencies. In 1955 the United States Public Health Service surveyed the water supply situations of cities of population of 25,000 or more. The following disturbing conditions were found:

One out of five cities was deficient in supply.

Two out of five were deficient in transmission capacity.

One out of three was deficient in pumping capacity.

Two out of five were deficient in treatment capacity.

Mr. Cramer presented this address at the 65th NFPA Annual Meeting, May 15–19, 1961, Detroit, Mich. Mr. Cramer is a partner of Fulton & Cramer, Consulting Engineers, Lincoln, Nebr.

The NFPA and the AWWA have worked diligently to provide public water systems adequate to deal not only with the normal water requirements of the community but also those which were imposed by the fires in the community and particularly the conflagration possibilities.

It was early realized by water works engineers that a generous proportion of the plant and distribution system of water works must be devoted to furnishing water for fire fighting. A few years before the great conflagrations in Baltimore and San Francisco, the National Board of Fire Underwriters had asked the NFPA to develop a standard for fire protection features of public water systems. An NFPA committee did this in 1903. Following the great conflagrations referred to, the National Board employed a sufficiently large staff of engineers to work on this problem with the water works people. From that work we have had a happy result of public water systems stronger and better designed for public fire protection than those of most other countries in the world.

The NFPA and the AWWA have both maintained technical committees which have worked over the many technical details which affect the usefulness of public fire protection equipment. Among obvious items have been the standardization of hose coupling threads and the design of hydrants.

Among continuing problems are those to work out a satisfactory method of handling connections which are made to a public water system for private fire protection. A new problem competing with the fire protection demand is one posed by the demands made on a public water system for water for use in air-conditioning systems.

Ground and elevated distribution storages showed deficiencies of 29 per cent and 43 per cent, respectively.

Distribution system improvements were needed in 57 per cent of the systems.

These figures are nearly six years old, but there is evidence that conditions have not improved since this survey. For instance, in 1957 and 1958, the NBFU reported new surveys on conditions in 89 cities which they had previously surveyed. The NBFU found that since the previous survey, 47 per cent had improved, 12 per cent had held their own, and 41 per cent had retrogressed. A further disquieting fact about the figures of the Public Health Service is that that study reported only on those cities having a population of 25,000 or more. Of the nearly 20,000 public water supply utilities in the United States, both publicly and privately owned, about 90 per cent serve populations smaller than 25,000; 86 per cent serve populations smaller than 10,000. Further, conditions are not as good in the small as in the large utilities. So it is obvious that there is a considerable need for upgrading water utilities. It should be emphasized that the deficiencies reported relate only to the improvements needed to bring the systems up to a capacity adequate to handle the existing loads. They include no estimate of facilities required to serve expanding populations and growing industrial requirements.

Other Problems

Naturally, there are other problems in the water works industry. Each separate system is a separate utility confronted with the day to day problems of financing, plant adequacy, and procuring an adequate supply of raw material; they are the same basic problems which are faced by any utility.

The Problem of Water Rights

The problem of insuring an adequate supply of raw material is probably more severe and complicated for water systems than for any other type of utility. A gas system, even though price negotiations may be difficult, can simply buy its product on the market. Likewise, an electric system often buys its energy for resale, and if that is not available at a reasonable price, at least a generating plant can be built, and the energy can be manufactured by buying the necessary fuel and setting up the necessary organization.

Water systems, on the other hand, have to build, operate, and maintain the costly structures and processes required to gather the water as a raw material and then to treat it to the point that it is an acceptable finished potable supply. They have to make it available in sufficient quantity for normal needs plus reserves for fire fighting emergencies. It is true that, normally speaking, water systems do not have to pay for their raw material as such. The industry has long made much of the slogan: "Water is free, all you have to do is to take your bucket to the river and collect what you want. Of course after that you have to bring it back from the river, treat it so that it is safe to drink, store it in sanitary containers till you need it, and then deliver it to your various points of desired use." This, of course, is intended to convey to the public the thought that their water bills do not pay for the water itself but for the operations which have been performed upon it to gather it, to make it safe and pure, and to deliver it under pressure to the exact point where the user wants it.

Competition for this "free" water is increasing so rapidly that the water industry in many areas is severely pressed to acquire enough for the needs

of its urban systems. This competition comes from agricultural interests who want more and more water for irrigation. It comes from the ever increasing demands of industrial processes. It comes from the fact that, as our populations grow, *per capita uses continue to soar.* Whereas a few years ago a stream may have contained completely adequate water for, say, two or three adjacent cities, growing demands for water may now make it impossible for the requirements of the downstream user to be met if those of the upstream user have first been completely fulfilled.

Of course, by far the greater portion of an urban supply is returned to the stream. Unfortunately, it is often returned so polluted as to be unfit for immediate reuse. This part of the problem can and must be solved by increased efforts to treat our sewage wastes adequately.

Thus, water systems face serious problems in respect to their rights to adequate supplies, and these problems are increasing. They must be solved or our cities not only cannot grow, they will die. If there is not enough water even for domestic, commercial, and industrial needs, there certainly will not be enough for fire emergencies.

Training of Personnel

As in all utilities, there is a need for training new men and for upgrading the training of all personnel as they progress through the utility organizations. This training must be provided for a considerable variety of skills: plant operators, chemists, distribution people, engineers, accountants, managers, and so on. It is very difficult to make such training easily available to all water utility men because, except for a few of the privately owned ones, most water utilities are operated as separate and isolated enterprises having little contact with each other except through organizations such as AWWA. Many water companies are small and are operating under penny-pinching rate structures which leave no funds for training. Many of the very small ones are operated by one or, at most, two men. Many of these men have other duties, such as police work or the management of other municipally owned utilities, and have little or no time for study and training. Many are even denied by their governing bodies the very modest cost of membership in AWWA. Thus, they cannot be reached with even the degree of training which periodicals, standards, and manuals could bring them, nor can they attend short courses which would qualify them to do their jobs better.

Financing

Of course, most of the problems of the water works industry could be solved by sufficient money. The financing problems of water utilities are not much different than those faced by other types of utilities. Somehow the public must be made aware of the needs and persuaded to vote the necessary bond issues and accept the necessary rate increases to build and operate the required facilities.

Walter Picton of the Business and Defense Services Administration has estimated that to correct just the current water system deficiencies will cost approximately five billion dollars.

To serve our estimated 1980 population of 258,000,000, it is conservatively estimated that an additional 16.2 billion dollars will have to be invested for system extensions.

It is an ambition of the water industry to upgrade the quality of the water. Simply sufficient water, barely safe enough to drink, at the right place and at the right time is not enough. The AWWA believes it should continually

strive to lower turbidity, to eliminate tastes, odors, corrosiveness, and staining properties and to provide softening where it is indicated. The American people have traditionally demanded quality in all of the goods and services which they use, and they have been willing to pay for it. It is hoped that they will finally come to feel the same way about water. The AWWA has estimated that the cost of upgrading the quality of our nation's water will be in the neighborhood of 1.9 billion dollars.

Thus, if current deficiencies are to be eliminated, if supplies are to be provided for expected populations of twenty years hence, and if the quality of water is to be improved, the water industry faces an over-all investment of 23.1 billions of dollars. If spread over the twenty years for which it will be spent, it will represent a total annual outlay of 1.65 billion dollars a year. When it is remembered that the water works industry's total construction expenditure in 1959 was approximately 500 million dollars, it is easy to see that, far from making progress, it has been backsliding.

Lack of Public Awareness of the Problems

The water and sewage treatment industries are probably confronted with a greater degree of public apathy in the solution of their problems than are any other utilities. People have come to take for granted that safe water will flow when they turn the tap, and that their wastes will be flushed away to trouble them no more when put down the drain. "Out of sight, out of mind" is the fate of the vast underground network of water and sewer pipes which cost so much and do so much for all of us. People sometimes have so little regard for the importance of these facilities that they have to be restrained from planting shrubs to hide that "unsightly" fire hydrant on the corner. Only when the water fails to flow from the tap, when the wastes fail to disappear, when there is inadequate pressure at the time of a fire, or when the firemen cannot effectively use the bush-covered hydrant, do they become aware of their utter dependence on urban water and waste systems.

Some Solutions Are in Sight

Some of the problems of the water industry are being solved, and the others can be solved.

The problem of water rights is one which will, in many cases, be settled by legislation. The members of AWWA, both individually and collectively, will continue to seek adequate supplies for urban customers in the formation of that legislation and will continue to urge that the usefulness of existing supplies be not allowed to shrink because of unabated stream pollution. The NFPA has a stake in this effort too. Water cannot be delivered to a hydrant if water companies are not allowed to take it from the streams or the aquifers.

AWWA is currently moving satisfactorily in the matter of the training of water works personnel. A committee on education has recently been created, and its chairman has been given the status of a member of the board of directors. It is hoped that ultimately a uniform system of courses can be made available through which a man may acquire the necessary knowledge and skills to perform more safely at his present level of responsibility and to qualify himself for advancement. Perhaps these can be offered through correspondence so that the cost will be low and so that the trainees will not have to be absent from their regular employment for more than a few days to witness demonstrations, perform actual field work, and take examinations. Hopefully the day will come when every

water works in the country will be operated by men who hold certificates attesting to their ability to do their jobs.

But the AWWA cannot teach the man it cannot reach. As previously mentioned, many small operators, those who need training most, are denied the small sum of fifteen dollars a year for individual AWWA membership. A suggestion by NFPA members that the water utilities in their communities be operated only by men who have proven qualifications for their jobs would be a long-run advantage to fire protection. Men who have at least a fundamental knowledge of hydraulics will be most apt to operate water systems where pressures are adequate.

The problem of financing the needed improvements in our water systems is really the problem of making the public aware of the needs. Once the public has been persuaded of the needs and of the grave results of neglecting them, the necessary funds will be forthcoming without difficulty. This persuasion is a public relations job which the AWWA is trying to do, and its efforts are meeting with increased success. Here again, the NFPA and AWWA should make common cause. AWWA and the water works industry possess the knowledge, skills, and other necessary tools to improve the water supply systems of our country to the level which our people deserve. We are anxious to share our knowledge with those who need it, and we are anxious to acquire from others any related knowledge and skills which will help us to inform our citizens to the end that they will willingly provide the financing required to do a better job of public water supply.

Interior Finish for Life Safety from Fire

By Robert S. Moulton

Consulting Fire Protection Engineer
Secretary, NFPA Committee on Safety to Life
Member, Society of Fire Protection Engineers

The Building Exits Code of the National Fire Protection Association, NFPA No. 101,* now available in its 18th edition, is designed to provide reasonable safety to life from fire. It specifies exits sufficient to permit evacuation of buildings promptly, together with various other features considered necessary by the Committee on Safety to Life to minimize the danger of panic and the possibility that occupants may find their path of escape blocked by fast spreading fire or by smoke, the greatest fire-killer, before they have time to leave the burning building.

*Published separately and in National Fire Codes, Volume III.

Interior finish, by which we mean the exposed interior surface of rooms and corridors, is an important factor in life safety from fire. The earlier editions of the Building Exits Code were based upon buildings which, for the most part, had plastered walls and ceilings with combustible interior finish limited to a great extent to solid wood wainscoting. The early editions of the Building Exits Code did not contain any regulation of interior finish, but as more and more combustible finishes came into common usage in buildings of all occupancies, it was felt that the code should also regulate the combustibility of interior finish.

T. R. Sorgi

Cleveland Hill School, Cheektowaga, N. Y., March 31, 1954; 15 killed. The untreated fiberboard ceiling finish of the classrooms and corridor of this 1-story building was partly responsible for this tragic fire. Delayed discovery, lack of sprinklers, and absence of exits directly outside from individual classrooms were among other contributing factors. For report see April 1954 QUARTERLY.

Untreated fiberboard and plywood or veneered paneling, which easily delaminated due to the type of glue used, were involved in several loss of life fires before the hazards of such finish were realized. It should be noted that other factors, particularly open stairways, were also involved in these fires, but the combustible interior finish obviously was a factor in the rapid spread of the fire through the buildings involved, which, in some cases, had even made the authorities prone to suspect arson and to look for traces of something like gasoline.

Interior Finish, Not Construction

Such obvious defects as open stairways, combustible concealed spaces, and highly combustible interior finish were often found in buildings of combustible classes of construction. For this reason, there has been a general denunciation of combustible construction as responsible for loss of life in fires. This idea is erroneous, as the structural framing of a building, which actually determines whether or not a building is combustible, has little to do with the hazard from fire to people in the building. It is rather the obvious fire-safety defects, which can be found in any improperly constructed building, whether it be of combustible or so-called fireproof or fire-resistive construction, that are responsible. The proper approach is to say what we actually mean and to restrict those things which do contribute directly to loss of life by fire.

Realistic Regulation of Interior Finish

If only noncombustible materials were used, there would obviously be no need for regulation of interior finish, but this, of course, is unrealistic since regulations to this effect, if applied literally, would prohibit even ordinary paint or wallpaper, as each introduce some element of combustibility. Contents of buildings are quite generally combustible, and, as a matter of fact, most fires start in contents and only spread to interior finish after they are well under way. There is thus no point in restricting finish to strictly noncombustible types, while at the same time having nothing to say about what anybody brings into a building. What is needed is some reasonable restriction, designed to safeguard life by eliminating the material for extremely rapid flame spread, but avoiding unnecessary hardship to the builder and maintaining a balance between combustibility of contents and combustibility of interior finish. This the NFPA Committee on Safety to Life has tried to do in drafting the Building Exits Code.

The Tunnel Test

While the principle received recognition in the Committee some twenty years ago, its actual incorporation in the Building Exits Code was necessarily delayed until some generally accepted method of measuring combustibility became available, a method which realistically measured rate of flame spread, and equally important, amount of smoke generated, under conditions closely simulating actual fire. This came in the so-called tunnel test, originated by Underwriters' Laboratories and now an official NFPA Standard, No. 255, Method of Test of Surface Burning Characteristics of Building Materials.* This test method has also received recognition by the American Society for Testing Materials. Originally it was viewed with skepticism by reason of the fact that only one test tunnel was available.

As more and more published test results on interior finish materials became available as a result of continu-

*Published separately and in National Fire Codes, Volume III.

W. A. McDonnell

Cedar Grove Nursing Home, Hillsboro, Mo.; October 31, 1952; 20 killed. Untreated fiberboard appeared to have been an outstanding factor in this fire. For report see January 1953 QUARTERLY.

ing activity by Underwriters' Laboratories in this field, as additional standard test tunnels were constructed by various people, particularly by Underwriters' Laboratories of Canada and by the Southwest Research Institute, and as the results of tests in the different tunnels were brought into harmony through a comparative test program, the tunnel test has come into increasingly widespread recognition and is the generally accepted standard of the combustibility of interior finish in the building code field. Recent full scale tests conducted by the Los Angeles Fire Department* have confirmed the validity of the tunnel test and have shown that the ratings of interior finish materials by small scale tests will not give an indication of their performance under actual fire conditions.

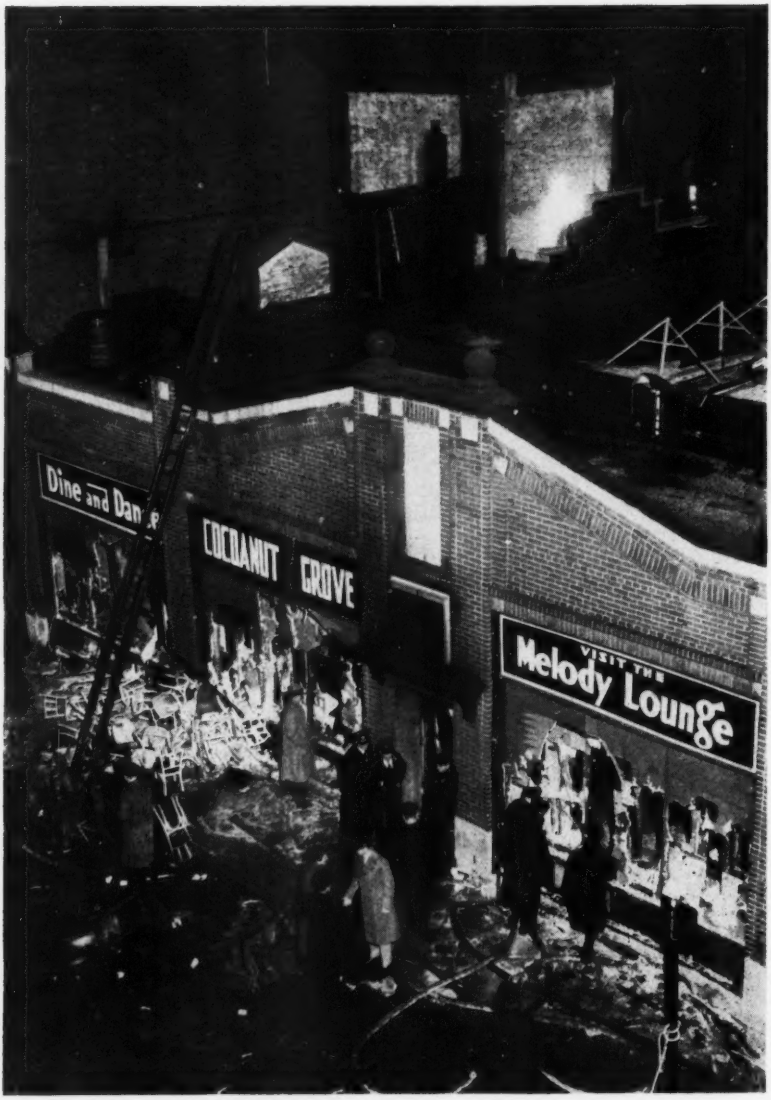
*Results of tests will be included in Operation School Burning No. 2 now being prepared for publication by the NFPA.

Interior Finish Combustibility Classes

The tunnel test rates interior finish materials on a scale in which asbestos-cement board is 0, and unfinished red oak is 100, red oak having been selected because, unlike most other woods, it has uniform burning characteristics, and samples purchased at random in various parts of the country have uniform rating. The Building Exits Code, using the tunnel test as a criterion, establishes classes of interior finish as follows:

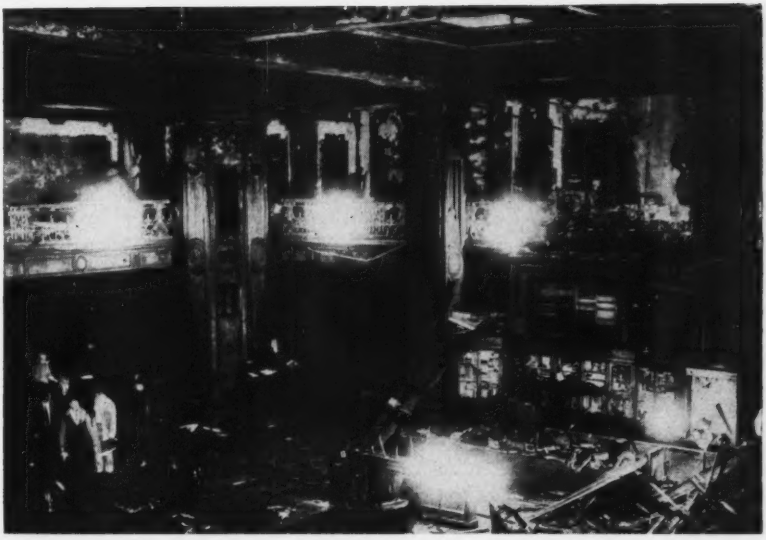
Class A	0 to 25
Class B	26 to 75
Class C	76 to 200
Class D	201 to 500
Class E	over 500

Practically all interior finish is restricted by the Building Exits Code to the first three classes, that is, with flame-spread and smoke-generation rating not more than 200. The need for this classification is illustrated by the



International News

Cocoanut Grove Night Club, Boston, Mass., November 28, 1942; 492 killed. Cotton cloth fastened to the underside of beams, a jammed revolving door, locked doors, a door that swung in, combustible decorations, and overcrowding were responsible for this holocaust. The cotton cloth had a flame-spread rating of 2,500 and fell into the classification of "interior finish" since it covered the ceiling of the basement cocktail lounge.



Press Association, Inc.

La Salle Hotel, Chicago, Ill., June 5, 1946; 61 killed. The fire originated in the cocktail lounge (not shown) that communicated with the lobby (shown above). As soon as the highly combustible interior finish of the lounge was involved, the fire spread rapidly into the lobby, where the highly varnished walnut veneer ignited and delaminated. See July 1946 QUARTERLY.

Cocoanut Grove night club fire in Boston, November 28, 1942, 492 dead, where the finish of the ceiling of the basement cocktail lounge, where the fire started, had a rating of 2,500, and by the LaSalle Hotel fire in Chicago, June 5, 1946, 61 dead, where the rating of the interior finish was well over 500. The Cocoanut Grove ceiling was cotton cloth fastened to the under side of the beams, and the finish in the lobby of the LaSalle Hotel was hardwood veneer held with glue that quickly softened under heat.

Building Exits Code Requirements

Table 1 summarizes the principal requirements of the Building Exits Code for interior finish in new buildings. For existing structures the requirements are slightly modified. The provision of a complete automatic sprinkler system justifies relaxation of the provisions of the Code, but not below Class C, on the theory that with Class D or more, combustible finish fire might spread over the surface more rapidly than sprinklers would open.

Another provision which modifies the requirements of the Building Exits Code on interior finish is the permission to have not over 10 per cent of the exposed interior surface of walls and ceilings of a higher flame-spread classification than the general requirement applicable. This permits the use of ordinary wood trim, cork bulletin boards, and the like, which may have a higher flame-spread rating but are not significant when their area is relatively small.

Combustibility of Unexposed Surface

Interior finish has another side, the back or unexposed face, and where this face is actually exposed in some combus-

tible concealed space, the combustibility of the back side of the finish is also an important factor. This is regulated in the Building Exits Code both as to combustibility and as to the area of the concealed space. This is not difficult to deal with in new construction but presents a serious problem in existing construction, as short of very extensive alterations, it is not feasible to treat the back side.

Tests made of the exposed surface securely affixed to a noncombustible backing are not necessarily indicative of the behavior of a single thickness of finish material which is open in a concealed space above or behind.

Still another factor of paramount importance is the character of the adhesive used to affix interior finish materials, such as acoustical tile. Where the adhesive used has a low melting temperature, the adhesive can soften and let the tiles fall, perhaps contributing to the fire. All this can be taken care of if the tests are made with the tiles affixed in the manner in which they are to be eventually used with the same adhesives or other methods of fastening.

Finish in Existing Buildings

Unfortunately, there are still countless buildings, erected before the general application of flame-spread requirements on interior finish, which have highly combustible finishes of various kinds. There are two answers to such situations — one to install automatic sprinklers, and the other to use a flameproofing paint. There are a number of flameproofing paints that are listed by Underwriters' Laboratories, and any one of these should be sufficient if applied in accordance with the manufacturer's instructions. A word of warning is in order here as some of these paints are subject to deterioration with age, particularly in the presence of moisture, and it may be necessary to recoat the surface periodically.

Most Finishes Now Class C or Better

The interior finish requirements of the Building Exits Code are not unduly stringent and yet they are considered safe, providing the building has other proper fire safe construction features, such as properly enclosed stairways and other vertical shafts as required by any modern building code.

Solid wood of almost any species qualifies as Class C with a flame-spread rating of 200 or less. The fiberboard manufacturers through the Insulation Board Institute have assured the National Fire Protection Association that all fiberboard materials of United States manufacture designed for interior finish uses are now being treated to assure a flame-spread rating, on the exposed surface, of not over Class C, a maximum of 200. Most fiberboard manufacturers also produce Class B materials, with a flame-spread rating of not more than 75. This has been confirmed by recent tunnel tests sponsored by the fiberboard manufacturers at the Southwest Research Institute, which showed that all fiberboard ceiling and wall tile which was tested qualified as Class C.

Thin veneer often used on interior finishes for decorative purposes may well be hazardous where the adhesive used does not have sufficient heat-resisting properties, but here again plywood is available which has been tested by Underwriters' Laboratories with indication of its flame-spread properties.

Smoke Generation

Smoke generation with materials like wood follows fairly closely the flame-spread rating. With certain materials, such as, for example, plastics, it may be that the smoke generation will be high, even though the burning charac-

Table 1

Condensed Summary of Interior Finish Requirements for New Buildings in the Building Exits Code

For complete details, see Building Exits Code, NFPA No. 101

OCCUPANCY CLASS	EXIT WAYS, Including Lobbies and Corridors		OTHER SPACES	
	Unsprinklered	Sprinklered	Unsprinklered	Sprinklered
Places of Assembly (Theaters, churches, exhibition halls, passenger stations, restaurants, etc.)				
200 persons or more capacity.	A	B	B	C
Under 200 persons capacity, including individual rooms in any place of assembly.	B	C	C	C
Educational (Schools, colleges, etc.)				
Ordinary buildings.	B	C	C	C
Open plan buildings.	B	C	B	C
Institutional				
Hospitals, nursing homes, old age homes, nurseries, prisons, etc.	A Including all rooms over 4 persons capacity.	B	B Applies to rooms not over 4 persons capacity.	C
Residential				
Hotels	B	C	C	C
Apartments	B	C	C	C
Dormitories	B	C	C	C
Lodging Homes (less than 15 persons)	C	C	C	C
Dwellings (1 or 2 family)	C	C	C	C
Mercantile				
Over 3000 square feet				
Ceilings	B	C	B	C
Walls	B	C	C	C
Under 3000 square feet (Street floor only)	B	C	C	C
Office	B	C	C	C
Industrial				
General	No difference between exit ways and other areas.		C	C
High Hazard			Not permitted	C D by special permission.
Storage	----------No requirements----------			
Miscellaneous				
Emergency Shelters	A	A	A	A

Press Association

Catholic Home for the Aged, Garfield Heights, Ohio, February 2, 1946; 14 killed. Fire spread so rapidly on the plywood ceiling and partitions, that many of the residents could not leave their rooms. In addition to the quick burning nature of the building, other factors that contributed to the loss of life were: lack of sprinkler protection, delayed fire department notification by attendants, panic, a 20-mph wind, and lack of division walls. For report see April 1946 QUARTERLY.

teristics are low. This is a point which should receive careful consideration.

How Does It Burn?

What is most needed in respect to interior finish is a general realization on the part of owners, architects, and builders, that proper control of interior finish is important, as well as other fire-safe construction features. Just to specify a fire-resistive or noncombustible building, does not by any means satisfy fire safety needs. If all manufacturers of interior finish materials were asked to supply evidence of the flame-spread and smoke-generation properties of their products every time that they were ordered for any building job, the situation would soon be greatly improved.

The following is one typical example. In a new hospital, the architects decided to use a plastic flooring material as a wall covering. This flooring material was easily kept clean, had a fine appearance, and was thoroughly satisfactory for use on floors. Architects, therefore, decided to try it on walls without thought of possible fire hazard. They apparently did not realize how essentially different in fire hazard a floor is from a wall, the floor being the last point to ignite in any fire. Except in some particularly hazardous situation, such as when wooden floors are oil-soaked, they can be practically neglected as a factor in life safety from fire. On walls, however, the situation is entirely different. At last reports, the hospital in question still had the floor tile on the corridor walls, and no one knew what its flame-spread characteristics were.

There are still all too many materials in use as wall and ceiling coverings where no one knows their rating in the tunnel test simply because they have never been tested. There are, however, many different materials produced by many different manufacturers that are available for interior finish with definite information as to their flame-spread rating, and the conscientious owner, architect and builder, should use these.

Sprinklers for Palletized Whiskey Barrels

A Report of Fire Tests Conducted by Underwriters' Laboratories, Inc.

Sponsored by the Factory Insurance Association

Tests on barrels of whiskey stored on pallets four tiers high demonstrate that fires in such storage can be satisfactorily controlled with automatic sprinklers discharging water at a minimum discharge density of 0.35 gallons per minute per square foot.

Alcohol spill fires in whiskey warehouses so protected can be satisfactorily controlled and extinguished by dilution of the spilled alcohol. Fire involving ordinary combustibles under such conditions can also be controlled and localized to the area of origin. Extinguishment of these localized fires may require 50 minutes to an hour of sprinkler discharge, and, even then, remaining smoldering materials may have to be extinguished with hand hose lines. Substantial water supplies are needed to provide for this continuing high density sprinkler discharge.

If leaking barrels of whiskey are involved, extinguishment will be delayed until such leakage ceases.

When lesser sprinkler discharge densities are used, control and extinguish-

Photo 1. Front face of each test pile was 26 feet wide by 13½ feet high. The pile was three pallets deep (19½ feet) in Tests 1, 2, 3, and 4, and four pallets deep (26 feet) in Test 5. The concrete blocks formed a dike around the pile. Ceiling sprinklers were on a 10-foot by 10-foot spacing.

ment will be delayed and the amount of fire damage increased.

These are the principal conclusions reached by the fire tests conducted by Underwriters' Laboratories, Inc. The tests were initiated and sponsored by the Factory Insurance Association and conducted with the cooperation of Hiram Walker & Sons, Inc. (which furnished the wood pallets, the oak barrels and test alcohol), the National Automatic Sprinkler and Fire Control Association (which provided the sprinkler test piping), and the Alcohol and Tobacco Tax Unit of the United States Treasury Department (which made it possible to use a specially denatured alcohol to simulate whiskey).

Need for Tests

The impetus to make this study resulted from a new method of storage for whiskey in barrels in bonded warehouses developed by Hiram Walker personnel. This method essentially consists of storing the barrels on wooden pallets, nine barrels to a pallet, with the pallets piled four tiers in height (13 feet, 4 inches), in essentially a solid pile. Photo 1 shows this new method of palletized storage, and Photo 2 shows a typical pallet. Concern was felt that this piling method offered more resistance to effective water distribution from overhead sprinklers than earlier industry storage practices where the whiskey was stored in wooden, single steel, and double steel racks.

Previous test work* covering whiskey rack storage had established that sprinklers could be expected to control fires under such conditions. The tests reported here sought to establish:

*Processes, Hazards and Protection Involved in the Manufacture of Spirituous Liquors (NBFU Research Report No. 5), published by the National Board of Fire Underwriters in 1956.

Photo 2. Pallets were 6 feet square, consisting of two slatted decks of 1-inch lumber on six 2-inch by 4-inch members.

(1) if fires in whiskey stored in barrels on pallets tiered four high could be extinguished,

(2) if this method of storage would cause undue delay in opening of sprinklers or the opening of an excessive number of sprinklers,

(3) if such fires would spread laterally, unchecked by sprinkler discharge,

(4) if such fires would involve the pallets or barrels to the extent that they could not be extinguished without doing considerable structural damage to the pile or tiers with subsequent dropping and breaking of barrels.

Test Method

The tests were conducted at the Northbrook (Illinois) Testing Station of the Underwriters' Laboratories, Inc. The room in which the tests were conducted is 37 feet wide by 66 feet, 7 inches long with a concrete floor, drained by open trenches (covered by steel grating) around the perimeter and across the center connecting to an outside drain. The walls are masonry and the ceiling is vermiculite plaster on metal lath, suspended from the roof

trusses, with ceiling heights of 21 feet in one half and 24 feet in the other half.

The tests were run in the 21-foot-high portion of the test room. Sprinklers were installed in this area on a 10-foot by 10-foot spacing with individual sprinklers located with their deflectors 7¾ inches from the ceiling and 7 feet above the top of the test pile. There were no sprinklers in the 24-foot-high part of the room.

The sprinkler piping was hydraulically calculated to permit selection of sprinkler discharge densities desired. The calculated flowing pressure at the sprinklers was maintained during the tests as sprinklers opened by adjustment of the water supply valves.

The test alcohol used for the tests had a specific gravity (60°F) of 0.916, a flash point measured by the Tag closed tester of 70°F and by the Tag open tester of 80°F, a vapor density of 0.90, and a heat of combustion of 6,882 Btu per pound.

Sprinkler Operation

In Test No. 1 the sprinklers were allowed to discharge water as they opened, as in normal wet pipe system operation. In subsequent tests, the water discharge was delayed for 1½ minutes after operation of the first sprinkler to simulate dry pipe system operation.

Listed upright standard sprinklers, of ordinary degree temperature ratings, were used in all tests.

Water Supply to Sprinklers

The water supplied to the test space was fed through an underground 8-inch main from a 1,500-gallon-per-minute fire pump taking suction from a 4,000,000-gallon pond and fed also from a 100,000-gallon gravity tank on a 100-foot tower.

Pallet Arrangement

For Tests 1 to 4, a test pile, four pallets wide by three pallets deep by four pallets high, was constructed. This pile covered a floor area of 26 feet by 19½ feet and was 13 feet, 4 inches in height. Each pile contained 48 pallets and 432 barrels. The pallet arrangement is shown in Figure 1, page 55.

For Test 5 the test pile was expanded to four pallets wide by four pallets deep by four pallets high. This arrangement is also shown in Figure 1. This pile covered an area of 26 feet by 26 feet, was 13 feet, 4 inches in height, and contained 64 pallets and 576 barrels.

Barrels

The barrels used were filled with water to simulate the weight of a full whiskey barrel. In Tests 2, 3, and 4, eight barrels of alcohol were placed in the center of the pile at various levels. In Test 5, 16 barrels of alcohol were placed four on each level through the center of the pile.

In all tests the pallets were loaded, nine barrels to a pallet, and individual pallets piled by use of a forklift truck. Dry barrels and pallets were used for Test 1. In subsequent tests the barrels and pallets in the center portion of the pile were replaced with dry barrels and pallets, and the remaining pallets and barrels were partially dried between tests by use of a portable heater.

Floor Dikes

A concrete-block dike was constructed on the floor, surrounding the test pile. The diked area was varied during the tests consistent with the size of the test pile and amount of alcohol spilled.

Thermocouples

Twelve thermocouples were installed 2 inches from the ceiling of the test room. Six of these were located in the

sprinklered portion over the test pile and six were located in the unsprinklered portion. Eight thermocouples were installed in the test pile, located in the pallets on the second, third, and fourth level. Where possible, these thermocouples were fastened to interior surfaces of the pallets to avoid their being wetted by sprinkler discharge.

Temperatures were recorded by use of Minneapolis-Honeywell, Brown Instrument Division, 16 station, continuous recording potentiometer, to which eight of the ceiling thermocouples and the eight thermocouples in the test pile were connected. The remaining four ceiling thermocouples were read by use of a single point potentiometer and a selector switch.

Test Fires

Two methods of starting the test fires were used. In Tests 1, 2, 3, and 5, two or three barrels of 110-proof alcohol were spilled on the floor inside the diked area and ignited. In Test 4, a ball of cotton waste was soaked in gasoline, placed in the center of the pile at floor level, and ignited.

Observation of Test Fires

In each fire test, persons were assigned to record the opening of sprinklers, observe and record temperatures, and observe the general progress of the test fires. The observers were positioned at various places in the room and reported in turn to a person who recorded this data by use of a dictating machine. As the tests progressed it became more difficult to observe the progress of the fire accurately as smoke build-up in the test room forced the observers to retreat to the outside of the room. Some knowledge of the progress of the test fires during this period was gained by observation of thermocouple temperature readings at the various locations of the test pile.

In view of the difficulty of determining the progress of the fire, the water discharge in Tests 1, 2, and 3 was continued until the smoke in the test room and pile temperatures indicated satisfactory control and essential extinguishment.

After each test the test pile was partially dismantled and the individual pallets and barrels were examined for extent of damage.

Test Fires

Test 1

This test was conducted with the sprinkler system set for normal wet pipe system operation at a discharge density of 0.35 gallons per minute per square foot. Just prior to ignition, three barrels (150 gallons) of 110-proof alcohol were spilled in the diked area which extended 2 feet on two sides and 5 feet on the other two sides of the pile (total area 815 square feet). Approximately 15 minutes prior to ignition, one-half barrel (25 gallons) of 110-proof alcohol was spilled over the top of pallet D-7 to simulate a severely leaking barrel. All barrels and pallets were dry for this test.

The first sprinkler operated at 49 seconds after ignition followed by additional sprinklers operating up to a total of nine at 2 minutes, 4 seconds after ignition. No additional sprinklers operated after this time, and the recorded temperatures indicated the fire was under control, although recorded temperatures accompanied by dense smoke indicated that significant burning continued for at least 25 to 30 minutes after ignition. After this time, the smoke density gradually decreased and the sprinklers were turned off 60 minutes after ignition.

A few glow spots remained in pallets B-7 and C-7 which gradually burned

TESTS 1,2,3,4

TEST 5

TIER D (Top Tier)

9	10 x	11	12
5	6	7 x	8 x
1	2	3	4

13	14 x	15	16
9	10	11 x	12 x
5	6	7	8
1	2	3	4

TIER C

9	10	11	12 x
5	6 x	7 x	8
1	2	3	4

13	14	15	16 x
9	10 x	11 x	12
5	6	7	8
1	2	3	4

TIER B

9	10	11	12
5	6 x	7	8 x
1	2	3	4

13	14	15	16
9	10 x	11	12 x
5	6	7	8
1	2	3	4

TIER A (Bottom Tier)

9	10	11	12
5	6	7	8
1	2	3	4

13	14	15	16
9	10	11	12
5	6	7	8
1	2	3	4

Figure 1. The four diagrams at left show the arrangement of pallets in the first four tests (4 tiers of 12 pallets each). The arrangement of pallets in Test 5, in which there were 16 pallets in each of 4 tiers, is shown at right. In all tests each pallet held nine 50-gallon wooden barrels on end. "X" indicates location of thermocouples in the pile.

out. Significant damage to the test pile was confined to the center six barrels and pallets on all four levels (including pallet 7 on which the alcohol was spilled); a total of four damaged pallets and 24 charred barrels.

Test 2

This test was conducted with a sprinkler system set to simulate the discharge time delay of dry pipe system operation. The main control valve which was closed at the start of the test was opened 1.5 minutes after the first sprinkler opened, after which the pressure was controlled to give a discharge density of 0.35 gallons per minute per square foot.

Twenty-four dry pallets and 216 barrels were installed on all tiers of pallets 1, 2, 3, 5, 6, and 7. The remainder of the barrels and pallets had been dried overnight.

A leaking alcohol barrel was simulated during the test by spraying alcohol at a rate of approximately 1 gallon per minute over pallet 7, tier D.

Two barrels of 110-proof alcohol (100 gallons) were spilled in the diked area (580 square feet). The diked area had been moved so that the dikes were only 6 inches from the pile to determine if the piling of barrels would offer resistance to the heat released from the burning alcohol and retard sprinkler operation.

In Test 1 it was felt that water collecting on the floor in the diked area may have extinguished the fires in the lower pallets by immersion. To eliminate this effect, two 2- by 24-inch weirs were installed in the dike.

The first sprinkler operated at 1 minute, 15 seconds, followed closely by the operation of additional sprinklers. Apparently all sprinklers had operated by the time the water was turned on manually at 2 minutes, 55 seconds.

Although smoke prevented accurate observations of the test from this point on, study of the temperature record indicates that the fire was completely controlled, except for some localized burning at the simulated leak, by 3 minutes after the sprinklers were turned on. When the simulated leak was stopped (55 minutes), this fire was also extinguished. Significant damage was confined to pallets and barrels in pallets 2 and 3 on all four levels; a total of eight damaged pallets and 23 charred barrels.

Test 3

Conditions for this test were identical to Test 2 with the exception that the sprinklers were operated at an average discharge density of 0.20 gallons per minute per square foot. Eight dry pallets and 72 dry barrels were installed in all levels of pallets 6 and 7.

The first sprinkler operated 1 minute, 35 seconds after ignition, and all sprinklers, including the dummy sprinklers in the unsprinklered portion, had operated by the time the water was turned on at 3 minutes, 10 seconds.

General observations and the recorded temperatures indicate the fire was controlled approximately 5 minutes after the sprinklers were turned on, although temperatures above 200°F were recorded at the ceiling of the test area for an additional 30 minutes. Temperatures recorded in the pile indicate that fire continued at the simulated leak until the flow of alcohol was shut off at 44 minutes after ignition.

Significant damage was mostly confined to all levels of pallets 6 and 7. The degree to which pallets and barrels were burned was more severe than in previous tests and there were some glow spots remaining after the test. These were extinguished with hand lines. One of the barrels, filled with alcohol on pallet C-7, was found to be leaking slightly

when removed. There was a total of 9 damaged pallets and 32 charred barrels.

Test 4

This test was conducted to determine effects of a fire involving ordinary combustibles of moderate proportions.

The sprinkler system was again operated as a simulated dry system (see Test 2) with the pressure controlled to give a discharge density of 0.35 gallons per minute per square foot. The concrete block dike was removed for this test.

Twelve dry pallets and 108 dry barrels were installed in all tiers of pallets 6 and 7, and on tiers C and D of pallets 2 and 3.

The source of ignition was cotton waste soaked in two gallons of gasoline, placed on the floor between pallets 6 and 7.

The first sprinkler operated at 1 minute, 35 seconds followed closely by the operation of additional sprinklers. All sprinklers, including those in the unsprinklered section, had operated by the time the water was turned on manually at 3 minutes, 20 seconds.

The test fire was under control approximately 5 minutes after the start of water discharge. General observations and review of recorded temperatures indicate essential extinguishment was effected approximately 10 minutes after the start of water discharge.

Significant damage was confined to the pallets and barrels immediately above the ignition source, pallets 6 and 7 in all levels; a total of eight damaged pallets and 38 barrels.

Test 5

In Tests 1, 2, and 4 it was extremely difficult to assess how quickly the individual fires were extinguished although it appeared that, in each case, extinguishment was almost complete after 10 minutes of sprinkler discharge. Prior to the start of Test 5 it was agreed that the sprinklers would be turned off after 10 minutes of sprinkler operation to determine if there was any significant remaining fire.

The sprinklers were again operated as a simulated dry system (see Test 2) with the pressure controlled to give a discharge density of 0.35 gallons per minute per square foot.

Three barrels of 110-proof alcohol (150 gallons) were spilled in the diked area (729 square feet) which was located with the dikes 6 inches from each side of the test pile. A leaking alcohol barrel was simulated by spilling alcohol at a rate of 1 gallon per minute over the pallet on pallet D-7.

The pallets and barrels in the pile were completely dry in all levels of the center four pallets (pallets 6, 7, 10, and 11), and all other pallets and barrels had been dried with a portable heater for 1½ days. The pile size had been increased to four pallets wide by four pallets deep.

The first sprinkler operated at 1 minute, 5 seconds. Approximately 13 sprinklers in the test system had operated when the water was turned on at 2 minutes, 35 seconds.

At 10 minutes after the start of the test, the alcohol leak was turned off and at 12 minutes, 35 seconds the discharge from the sprinklers was turned off.

Within 2 minutes the smoke had cleared sufficiently so that considerable Class A fire could be seen in the test pile. This was accompanied by an increase in ceiling temperatures and opening of all remaining sprinklers in both the sprinklered and unsprinklered portions of the test room.

The sprinklers were turned on again at 15 minutes, 15 seconds. At 25 min-

Table 1

Summary of Sprinkler Tests of Palletized Storage of Whiskey in Barrels

Sprinklers Spaced 10 ft by 10 ft, 7 ft Clearance from Top of Pile to Deflector

	Test 1	Test 2	Test 3	Test 4	Test 5
Number of pallets in pile	48	48	48	48	64
Number of barrels in pile	432	432	432	432	576
Amount of alcohol spill and location	25 gals top of pallet 7, tier D, 3 bbls in dike	2 bbls in dike, 1 gpm flowing on pallet 7, tier D	2 bbls in dike, 1 gpm flowing on pallet 7, tier D	None	3 bbls in dike, 1 gpm flowing on pallet 7, tier D
Type of sprinklers	Grinnell Duraspeed 165° F	Grinnell Duraspeed 165° F	Automatic 165°F	Automatic 165°F	Viking 160°F
Average density of sprinkler discharge, gpm per sq ft of floor area	0.35	0.35	0.20	0.35	0.35
Pressure at most distant sprinkler, psi	37	37	12	35	35
Flow, gpm per sprinkler	33	33	19	33	33
Total flow from sprinklers, gpm	297	528	304	528	528
Time after ignition for first sprinkler to fuse	43 seconds	1 minute 18 seconds	1 minute 30 seconds	1 minute 35 seconds	1 minute 5 seconds
Total number of sprinklers to fuse in fire area	9	16* (all)	16* (all)	16* (all)	16* (all)
Diked spill area, sq ft	815	580	580	None	729
Maximum ceiling temperature	265°F	370°F	1,100°F	1,420°F	725°F
Maximum temperature in pile	505°F	1,550°F	710°F	1,680°F	340°F
Sprinklers shut off	50 minutes	1 hour	1 hour	25 minutes	25 minutes
Remarks	Sprinklers operated automatically, wet system	Water turned on manually 1 minute, 30 seconds after first sprinkler fused	Water turned on manually 1 minute, 30 seconds after first sprinkler fused	Water turned on manually 1 minute, 30 seconds after first sprinkler fused	Water turned on manually 1 minute, 30 seconds after first sprinkler fused, turned off after 10 minutes, turned on again in 2 minutes, 40 seconds

*In these tests, dummy sprinklers also operated in the adjoining 25-foot-high section of the test building.

utes, the recorded temperatures and observations indicated the fire had been essentially extinguished and the sprinklers were turned off.

Severe glow spots remained in pallets B-1, C-1, and D-1, and in the bottom of barrels in pallets C-1 and D-1, which were later extinguished by hand hose lines as the test pile was removed.

There was significant damage to 28 pallets of which 14 were located on the lowest level (tier A) and to 66 barrels of which 38 were located on the lowest level (tier A).

Summary of Test Data

Table 1 gives a summary of the test conditions and results.

An alcohol spill of one barrel (50 gallons) may be expected to cover an area of 1,000 square feet, a three-barrel spill approximately 1,600 square feet, a six-barrel spill about 2,400 square feet, and a nine-barrel spill about 3,000 square feet.

On the basis of tests with a one-barrel spill, it was concluded that sprinklers would operate in an area of 90 by 90 feet (about 8,000 square feet). With all sprinklers in this area discharging at a rate sufficient to provide a density of 0.35 gallons per minute per square foot on the floor, the water rate to supply all sprinklers would be 2,800 gallons per minute. The total supply for this condition for a discharge duration of 3 hours would be 500,000 gallons. For a nine-barrel spill, the area covered would probably require sprinklers to operate over an area of 13,000 square feet and this would require a water rate of 4,550 gallons per minute at the same density and a total supply for 3 hours of 820,000 gallons. If the spill was of an irregular shape, sprinklers would operate over an area as large as 16,000 square feet. Other variables that would influence the number of sprinklers that will operate are the arrangement of floor drains, the effectiveness of draft stops, the number of barrels which might break in event of a piling mishap, and whether the sprinkler system is designed for wet pipe or dry pipe operation.

Water supply requirements for sprinklers should be supplemented to provide for supporting hose streams.

Army Helicopter Accidents Involving Fire

By Captain Cecil H. Grimes

Army Board of Aviation Accident Research

Recently, an Army utility helicopter was flying cross-country to make a passenger pick-up. The weather was fine, and the crew, which consisted of a pilot, co-pilot, and crew chief, were congratulating themselves on their navigation procedures. They had the airfield in sight and had started their landing pattern. Just as the pilot started the approach, the engine quit. Both pilot and co-pilot instinctively initiated emergency procedures for autorotation. Just before touchdown, they flared the helicopter slightly to reduce ground speed and pulled pitch to soften ground contact. However, the application of pitch failed to stop the rate of descent, and the helicopter struck the ground hard, burst into flames, bounced, and rolled. When the aircraft finally came to rest, it was on its right side and engulfed in flames (see Photo 1). The co-pilot jumped outside, rolled on the ground to extinguish the flames on his clothing, and then crawled back into the cockpit to help the pilot out. With the pilot out of the flaming wreckage, he attempted to locate the crew chief, who was found struggling to get out of the flames and trying to ex-

Presented at the Aviation Seminar held in conjunction with the 65th NFPA Annual Meeting, Detroit, Mich., May 15–19, 1961. The paper was presented by Emil Spezia for Captain Grimes, who was on a fire accident investigation at the time of the Seminar.

Photo 1. The engine quit as this Army utility helicopter was about to land. Fire, that broke out when the aircraft struck the ground, fatally burned one of the three occupants and seriously burned the others.

tinguish the fire covering his body. The crew chief had either been thrown or jumped out of the aircraft during the ground roll. He died a week later from third-degree burns over 90 per cent of his body. The pilot and co-pilot received severe burn injuries. Had there been no fire, there would have been no injuries in this accident.

This is only one example of many Army helicopter accidents involving fire. Increasing the crashworthiness of the helicopter is one of the primary objectives in Army aviation today. This attention is necessary in the helicopter, as it does not have a suitable inflight escape system when there is engine failure, or other malfunction, preventing continued flight. The pilot, crew, and passengers are committed to "ride the aircraft down."

Army Helicopters

The Army is presently the world's largest operator of helicopters. The inventory of aircraft today indicates 50 per cent of our fleet is rotary wing. However, the helicopter is expected to comprise 75 per cent of the Army aircraft by 1970. In addition to the increased per cent of rotary wing aircraft in the inventory, the total inventory of aircraft in the Army is scheduled to increase. Planning figures indicate nearly 2½ times as many helicopters within the Army in the next 9 years as we have now. This added emphasis upon helicopters should call for an added emphasis upon problems inherent to the helicopter. One of these problems is fire.

To understand the crash-fire problem in the Army more clearly, seven types of helicopters presently operated in the Army, upon which this paper is based, are pictured in Photos 2 through 8.

Army Helicopter Fire Accidents

One of the most effective means of combating the accident fire problem is through accident review and analysis. The United States Army Board for Aviation Accident Research, or, as commonly called, USABAAR, makes a review and analysis of each accident and codes the information for IBM data processing. This study of accident experience is necessary for accident prevention purposes and for the design and development of future aircraft.

A survey of all Army helicopter accidents involving fire for the three-year period, July 1, 1957, to June 30, 1960, is summarized in Table 1. During this period, 42 fire accidents were experienced.

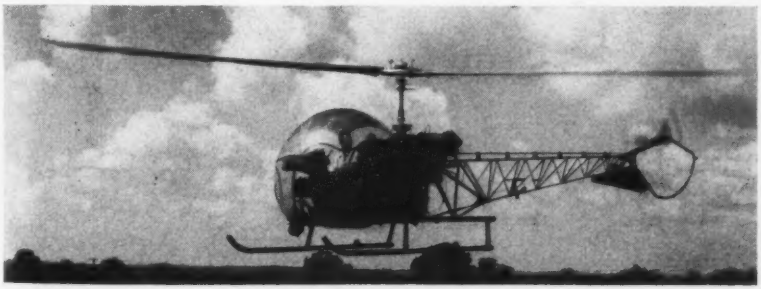


Photo 2. Within the reconnaissance group, the H-13, or Sioux, is the most widely used helicopter. This aircraft uses 91–96 octane fuel in the external fuel cells mounted on each side of the transmission and mast. Fuel capacity of model shown is 29 gallons. A later model of the H-13 has a 43-gallon capacity.

Photo 3. Another reconnaissance helicopter, the H-23, or Raven. The Raven uses 91–96 octane fuel. The fuel cell is bladder type and is located inside the basic body section of the helicopter, directly below the engine deck. This tank holds 46 gallons of fuel.

Photo 4. The H-19, or Chicasaw, is classified as a utility helicopter. It uses 91–96 octane fuel in two fuel tanks, a forward and an aft, located below the cabin floor. The forward tank consists of five interconnected bladder cells and the aft tank consists of three interconnected bladder cells. Fully serviced, total fuel is 183 gallons.

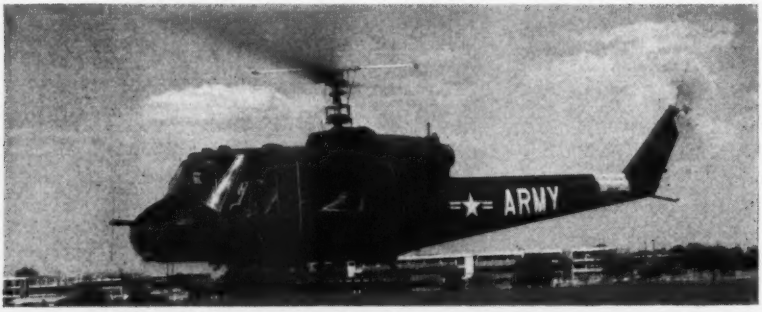


Photo 5. The HU-1A, or Iroquois, is the latest operational rotary wing aircraft to join the Army inventory. This is a gas turbine-powered helicopter and utilizes JP-4 fuel. There are two interconnected rubber cells located aft of the cockpit section and below the engine mounts. The fuel capacity is 155 gallons.

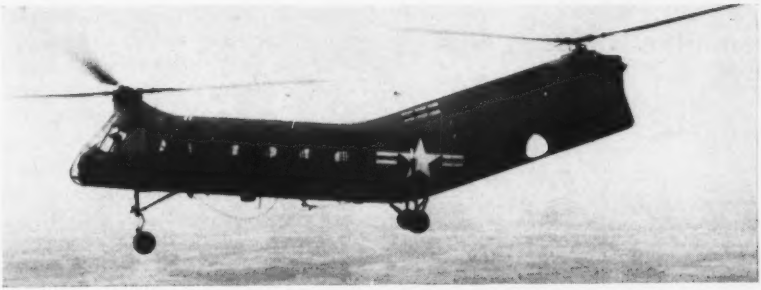


Photo 6. This helicopter is classified as light cargo. It is the H-21, or Shawnee. The fuel system incorporates one rubber fuel tank centrally located in the structure with provisions for attachment of two auxiliary fuel tanks as an integral part of the installation. Fully serviced, the main fuel cell holds 304 gallons of 100–130 octane fuel.

Photo 7. The H-34, or Choctaw, is also a light cargo helicopter. Fuel is carried in three multicell fuel tanks which are located in the forward fuselage section below the cabin floor. Fully serviced, the cells hold 263 gallons of 100–130 octane fuel.

Photo 8. This is the largest operational helicopter in the free world. The H-37, or Mojave, is classified medium cargo. The fuel system consists of two independent pressure-type fuel systems, a right engine fuel system, and a left engine fuel system. The fuel tank for each engine is located in the wing and nacelle behind the engine firewall. Fully serviced, the total capacity is 406 gallons of 115–145 octane fuel.

Table 1

Army Helicopter Accidents Involving Fire

July 1, 1957 — June 30, 1960

Model	Total Accidents	Fire Accidents	Per Cent Fire Accidents
H-13	231	12	5.2
H-23	113	7	6.2
H-19	55	4	7.3
H-21	101	9	8.9
H-34	58	6	10.3
H-37	9	2	22.2
HU-1A (H-40)	11	1	9.1
YH-41*	1	1	100.0
Total	**579**	**42**	**7**

*The YH-41 is a test aircraft.

It is interesting to note that each model helicopter has been involved in fire accidents. Exceptions should be made for the YH-41, which was only a test aircraft, and the HU-1A. The fire accident of the HU-1A was unusual. The fire originated from the heater exhaust located under the helicopter while operating in a tall dry-grass area. The exhaust ignited the grass, and the aircraft was enveloped in flames before the crew could extinguish it. Unfortunately, the aircraft became a total loss. Discounting the fire accident of the HU-1 and YH-41, the per cent of fire accidents to total accidents indicates an increasing rate as the models increase in size.

Collectively, fire accidents have accounted for 7 per cent of all Army helicopter accidents. During the same reporting period, a comparable study on fixed-wing accidents show less than 4 per cent of major fixed-wing accidents

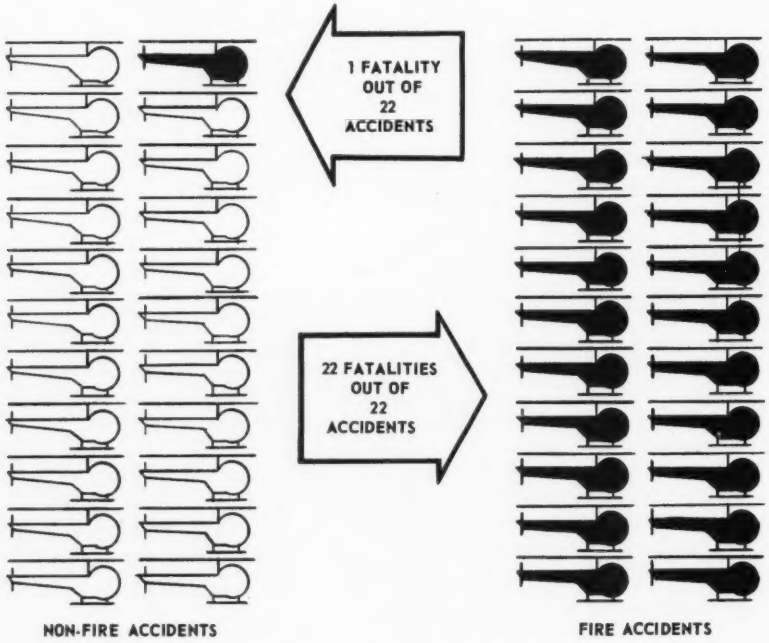


Figure 1. Comparison of fatalities in fire and nonfire Army helicopter accidents.

Table 2

Cause Factors in Helicopter Fires

July 1, 1957 — June 30, 1960

Cause Factor	Number	Per Cent Total Accidents
Ruptured Fuel Cells or Lines	33	78.5
Malfunction in Engine Compartment	7	16.7
Grass Fire (ignited by heater exhaust)	1	2.4
Unsecured Fuel Tank Cap	1	2.4
Total	42	100.0

involved fire. If we compare fixed-wing fire accidents to rotary-wing fire accidents, we find the Army has over twice as many fire accidents involving helicopters. These figures reveal the seriousness of fire in the helicopter accident. They become extremely alarming when the injuries involved are considered. During this three-year period, the Army experienced 65 fatalities in rotary-wing accidents. Of these fatalities, 41 or 63 per cent occurred in postcrash-fire accidents.

Comparing fatalities in postcrash-fire accidents with nonfire accidents, it was found that for each fire accident there is one fatality, whereas in nonfire accidents there are 22 accidents for each fatality incurred. In other words, the chance of survival in a nonfire accident is 22 times greater than in accidents involving fire (see Figure 1). The added danger of fire in an accident is revealed by the fact there were only 24 rotary-wing accidents in which burns were sustained, but these accidents produced 40 fatalities and 10 serious thermal injuries. The primary cause of death in 9 fatalities was listed by the flight surgeon as thermal injuries.

Cause of Helicopter Fires

Determining the cause of fire in an aircraft accident is usually a very difficult task for accident investigators. Fire cause factors, as given in accident reports, are summarized in Table 2.

Aircraft damage resulting from impact loads plus fire makes differentiation between ruptured fuel cells and ruptured fuel lines virtually impossible as the basic fire causation factor. All fire accidents, therefore, in which fire originated in the fuel cell area, have been placed in the same category. Inflight fires accounted for only three accidents. Two of these accidents originated within the engine compartment, and one resulted from an unsecured gas tank cap.

Need for Accident Research

The need for crash safety design in the modern helicopter is becoming increasingly important. The present day helicopter has increased its over-all speed capability, is carrying more personnel, and its missions require "nape-of-the-earth" flight techniques. These factors subject the helicopter crew to conditions more conducive to accidents and circumstances which tend to increase accident severity.

Many military and civilian agencies are working toward improved crashworthiness in current and future aircraft. The methods employed range from drawing board evaluations to dynamic drop testing procedures. The United States Army Board for Aviation Accident Research believes information and experiences gained from accident

research are necessary to determine crash-worthy deficiencies in present aircraft and represent a valid basis for recommendations in this area.

Fire-Safe Fuel System Design

An analysis of Army helicopter accidents involving fire shows a need for special considerations in the design and requirements for crash-fire-resistant fuel systems in the development of helicopters. Recommendations in this area include:

1. Location of fuel cells

It appears, unfortunately, that fuel cell placement on the helicopter has been an afterthought, with the fuel cells placed in an area that is not utilized by some other major component. From a crashworthy aspect, locating the fuel cells aft of the cabin area appears to

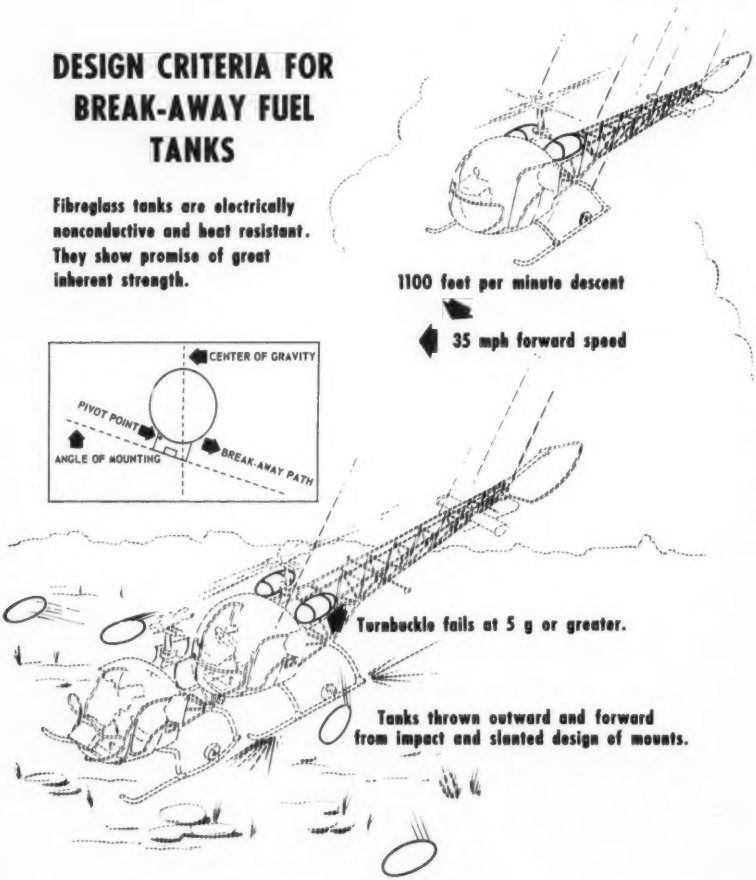

DESIGN CRITERIA FOR BREAK-AWAY FUEL TANKS
Fibreglass tanks are electrically nonconductive and heat resistant. They show promise of great inherent strength.
1100 feet per minute descent
35 mph forward speed
CENTER OF GRAVITY
PIVOT POINT
ANGLE OF MOUNTING
BREAK-AWAY PATH
Turnbuckle fails at 5 g or greater.
Tanks thrown outward and forward from impact and slanted design of mounts.

Figure 2. For helicopters with external fuel tanks, the feasibility of break-away fuel tanks is being studied. Glass fiber-reinforced tanks, that in a crash landing would be thrown outward and forward, are being investigated.

lessen the danger of fire to the occupants. This aft position is a decided advantage over the location under the cabin floor, which, during hard landings, is highly susceptible to rupture from impact damage by protruding structures, such as gear struts. Consideration of adjacent components is important. Items, such as transmissions and engines, can easily rupture or ignite the fuel during a crash sequence. The proximity of the transmission to the fuel area is extremely important. The forces transmitted from the rotor blades to the transmission when they encounter items such as trees, cables, or the ground, are usually of extreme magnitude and are known to displace the transmission or force it completely out of the aircraft. Damage to surrounding components is usually severe.

For helicopters which have external fuel tanks, USABAAR has initiated research in break-away fuel tanks. To determine the feasibility of this idea, our engineering section had a glass fiber-reinforced plastic tank constructed for installation on the present H-13 Sioux helicopter. The glass fiber tanks are electrically nonconductive, heat resistant, and show promise of great inherent strength. The tanks will be mounted so that the center of gravity is laterally positioned and the mounting straps engineered to fail at the turnbuckles when "g" forces exceed four and one-half to five g's (see Figure 2). On crash landing the tanks would be thrown outward and forward due to impact and the slanted design of the mounts. Aviation Crash Injury Research of the Flight Safety Foundation, in conjunction with USABAAR, is mounting the break-away fuel tanks on H-13 helicopters for dynamic drop tests this summer.

The need for this type of tank on helicopters having externally mounted fuel tanks is evident in the following accident history:

A reconnaissance helicopter had completed its mission of flying "cover" for a motor convoy and was looking for a suitable place to land. The pilot, with an observer in the right seat, flew over a location beside the convoy that appeared to be a good landing site. While making a low reconnaissance of the field, the helicopter struck a power line. The bubble shattered on contact with the wires. The drag of the wires, before breaking against the instrument console, caused the main rotor blades to flex violently and sever the tail boom. The helicopter hit the ground in a right bank attitude, coming to rest approximately 78 feet from the point of initial impact. The pilot stated he heard an explosion just after contact with the wires and another shortly after contact with the ground. Grass burns indicate the fuel cell was ruptured upon initial contact with the ground and that fuel burst into flames when the fuel came in contact with the hot engine. The bubble, having been shattered upon contact with the wires, left the pilot and passenger unprotected from the splash of fuel when the right tank was ruptured. Fire consumed all portions of the helicopter forward of the firewall and the right fuel cell was burned through in numerous places. When the aircraft came to rest, the pilot and the passenger unfastened their shoulder harness and safety belts and exited. The gasoline that had splashed over them was burning. Both occupants suffered second and third degree burns over 30 to 40 per cent of their bodies. Thermal injuries, the only ones involved, could have been prevented by properly functioning break-away fuel cells (see Photos 9 and 10).

2. Cell Construction

Self-sealing fuel cells are designed primarily for combat conditions to prevent

Photos 9 and 10. As reported on page 67, this helicopter was making a landing when it struck a power line. When the craft hit the ground, the right fuel tank ruptured. Spilled fuel burst into flames on coming in contact with the hot engine. Burning fuel splashed on the two occupants of the aircraft causing second and third degree burns on 30 to 40 per cent of their bodies.

fuel leakage due to gun fire penetration. The basic design consists of two bladders, one inside the other, with a sealing substance in between, which will plug any puncture-type hole. This is the sole characteristic of self-sealing fuel cells. Crash-resistant cells are designed to reduce personnel injury and aircraft damage in event of a crash or forced landing by absorbing or resisting the crash forces and preventing rupture. Crash-resistant systems provide protection throughout the life of each aircraft — during test and development, training, peacetime operation, and in combat. Self-sealing systems give protection only when exposed to enemy fire. The crash-resistant fuel cell should be of minimum thickness and weight necessary to contain the fuel and meet the strength requirement of the airframe. A rubber fabric would have a high degree of crash resistance due to the fact it can be deflected under inertia loads.

The French experience in Algeria and Indo-China substantiates the need for crash-resistant fuel cells over the self-sealing type. It has been reported that the effect of small arms fire on helicopters does not substantiate a requirement for self-sealing cells, because crash fire is the major problem. A summary of the French Air Force experience indicated that 88 per cent of the bodies found in the wreckage of crashed helicopters were charred or burned, and at least one-third of the deaths were attributable to burns. Practically all major crashes ended in a fire. USABAAR has concluded that more protection could be provided by requiring crash-resistant fuel cells rather than ballistic-proof fuel cells.

3. Enclosure

There should be energy absorbing material surrounding the fuel cell area. Impact or "g" forces transmitted to the cell area could be reduced by incorporating a honeycomb structure around it. This material can be lightweight, such as aluminum or glass fiber-reinforced plastic. The rigidity and strength of glass fiber in addition to its resistance to burning show considerable promise.

The HU-1A, a turbine-powered helicopter, possesses this type of fuel cell enclosure. HU-1A accidents have resulted in considerable damage to the fuel cell area without rupture of the bladders. This feature, added to its aft location, is considered the primary factor in giving the HU-1A its outstanding record of no crash fires to date.

4. Fuel Lines

Primary fuel lines leading from the fuel cell should have self-sealing disconnects. These connections should be incorporated between each compartment through which the fuel lines pass and should be the weak point in the line. This would result in the separation of the lines at the self-sealing positions before rupture of the primary line.

Fuselage Construction

Weight has always been of prime consideration in helicopter design and development. To reduce the weight, manufacturers have utilized material which was the lightest available and which possessed the strength properties required. Magnesium has been a popular metal for the present utility and cargo helicopters. However, because of its low kindling point and fast rate of burning, other alloys are generally recommended. If the occupiable area is constructed of an alloy with a higher resistance to ignition and rate of burning, the time between ignition and the fire reaching occupiable areas may be the difference between the occupant escaping or being burned.

Turbine-Powered Helicopters

The helicopters being designed today are known as "third-generation" helicopters and will create new and different problems. One such problem anticipated is the use of JP-4 fuel. The rate of consumption of the turbine engine is much greater than the reciprocating engine. This will require additional fuel loads for flights of comparable endurance. In addition, the fuel-air mixture or vapor of JP-4 will be combustible under most operating conditions of temperature, pressure, and altitude. This is in contrast with vapors from gasoline or kerosene, which would normally be either too rich or too lean and have a more limited combustion range for pressure, temperature, and altitude combination.

Conclusion

A crash-fire problem exists in the helicopter. Fatalities and serious injuries are resulting from postcrash fire. The aircraft dollar loss is excessive. The Army recognizes the fire problem and is attempting to minimize the dangers involved. This will not be accomplished overnight, nor will it be solved alone. Only through cooperation of all interested agencies and continued effort will the crash-fire hazard in helicopter operations be reduced to a negligible factor.

Meetings of the Board of Directors

Detroit, Mich., Monday, May 15, 1961

Members Present

T. Seddon Duke, Chairman
Loren S. Bush, President
J. Sharp Queener, Vice-President
Warren J. Baker, Vice-President
Henry G. Thomas, Past-President

W. H. Berry	Paul C. Lamb
A. Sidney Briggs	Elmer O. Mattocks
J. R. DeHaven	John H. Redmond
Frank J. Fee, Jr.	George F. Wahl
R. H. Ferguson	W. M. Wetzel
W. H. Forristall	

Percy Bugbee, General Manager

1. The report of the Board of Directors to be presented at the first general session of the annual meeting was read by Chairman Duke and approved.

2. The report of Treasurer Hovey T. Freeman to be presented at the first general session of the annual meeting was read by the Assistant Treasurer and approved with a vote of special commendation by the Board to the Staff.

3. Chairman Duke announced the appointment of the Technical Advisory Committee for 1961–62 as follows: T. Seddon Duke, Chairman, Warren J. Baker, E. W. Fowler, Paul C. Lamb, Elmer Mattocks, George Wahl.

4. The name of the Industrial Committee was changed to Industrial Management Committee at the request of the Chairman of the Committee, John Redmond.

5. The General Manager announced that the 1961 Fall Conference was scheduled for the Hotel President, Kansas City, Mo., October 30–November 1. Former Fire Commissioner Wornall of Kansas City has accepted the chairmanship of the local Sponsoring Committee.

6. It was reported that Distinguished Service Awards had been presented to members Raymond M. Hill, Fire Marshal of Los Angeles; John A. O'Donnell, Manager, Ground Safety, American Airlines; and J. N. Pryce, Director, Fire Protection Engineering Division, Canadian Underwriters Association.

7. The General Manager reported on the retirement of former Technical Secretary, Robert S. Moulton, on May 1 and the appointment of George H. Tryon as Technical Secretary on that date. Mr. Chester I. Babcock has been appointed Assistant Technical Secretary, Mr. Rexford Wilson as Fire Record Editor in the Fire Record Department, and Mr. Theodore Torrey, Jr., as Supervisor of Fire Records. It was also reported that Mr. Ernest Juillerat, Jr., of Dunbar, W. Va., had been added to the staff as of June 12, 1961, for work in the Fire Record Department.

8. It was voted to hold the next meeting of the Board at 10 A.M. on Monday, June 26, in Boston.

9. The General Manager made brief, informative reports to the Board on the electrical field service, the proposed project for rural field service, and the controversy on the proposed crash truck standard.

Boston, Mass. June 26, 1961

Members Present

T. Seddon Duke, Chairman
Loren S. Bush, President
Warren J. Baker, Vice President
John A. Neale, Past President
Henry G. Thomas, Past President
Hovey T. Freeman, Secretary-Treasurer

John J. Ahern
W. H. Berry
J. R. DeHaven
Frank J. Fee, Jr.
R. H. Ferguson
W. H. Forristall
Paul C. Lamb
Lewis A. Marshall
Elmer O. Mattocks
C. George Segeler
Carroll E. Shaw
George F. Wahl
W. M. Wetzel

Percy Bugbee, General Manager; Charles S. Morgan, Assistant General Manager; George H. Tryon, Technical Secretary; Horatio Bond, Chief Engineer.

Business Transacted

1. In accordance with the recommendation of the annual meeting, the following officers were elected: President, Loren S. Bush; Vice President, J. Sharp Queener; Vice President, Warren J. Baker; Secretary-Treasurer, Hovey T. Freeman; Chairman, Board of Directors, T. Seddon Duke.

2. Messrs. John J. Ahern and Lewis A. Marshall were elected to complete the Nominating Committee for 1962.

3. The schedule of annual meetings through 1965 was discussed. The selection of Chicago for the annual meeting in 1966 was tentatively approved.

4. The Program Committee for the 1962 annual meeting at Philadelphia was appointed. This consists of the President, the Chairman of the Board of Directors, and the General Manager.

5. Preliminary plans for the fall conference at Kansas City, Missouri, October 30–November 1 were reviewed and approved.

6. The report of the Treasurer, Hovey T. Freeman, was approved. This indicated a healthy financial condition despite the influence of a business recession in 1960 and continued heavy expenses in connection with the forthcoming edition of the *Handbook of Fire Protection*.

7. The budget for 1961–62 as submitted by the Finance Committee, consisting of Messrs. Freeman, Duke, and Bush, was approved.

Field Service and Section Reports

8a. The General Manager reported current developments in the activities of our Electrical Field Service Engineer and commented on the relationship with the International Association of Electrical Inspectors. He reported that the services of our Electrical Field Service Engineer, Mr. Stetka, are highly satisfactory. Mr. Tryon discussed the development of the 1962 edition of the National Electrical Code and the plans for publication this year of the proposed amendments. The high cost of publication of this preliminary material in the face of very limited demand was commented upon.

b. Mr. Mattocks reported on the Flammable Liquids Field Service, indicating great satisfaction with the services of our Flammable Liquids Field Service Specialist, Mr. Woodworth. He reported the production of a motion picture film for the training of fire service personnel in the control of fires at bulk oil stations. This film is being produced under the supervision of our Flammable Liquids Field Service Specialist with funds made available by the petroleum industry. The extraordinarily fine cooperation of the Tulsa, Oklahoma, Fire Department in conducting and controlling the demonstration fires was referred to, and it was voted to

express the grateful thanks of the Association to the Tulsa Fire Department.

c. Mr. Baker reported on the Gases Field Service Project and spoke of the highly satisfactory services of our Gases Field Service Specialist, Mr. Clark Jones. He mentioned recent state adoptions of NFPA Standard No. 58 and discussed several matters currently occupying the attention of our Gases Specialist.

d. Mr. Baker, President of the Society of Fire Protection Engineers, reported on the affairs of the Society and indicated general satisfaction with the membership growth and financial situation. He called attention to a new publication of the Society now in preparation entitled "Careers in Fire Protection Engineering," which, it is expected, will prove highly useful to vocational guidance counselors and to secondary school students.

e. Mr. Morgan reported on the Fire Marshals Association of North America, of which he is Executive Secretary. He referred particularly to the quality of officer leadership which the Association is enjoying and to the highly cooperative and mutually beneficial relationship which exists between this professional group and the NFPA.

9. Mr. Bugbee reported with indignation the service of subpoenas to several prominent members of the Association during the annual meeting at Detroit in connection with a law suit, Roofire Alarm Company versus Royal Indemnity Company.

10. Mr. Bugbee announced with satisfaction the continuation as Chairman of our Finance Campaign Sponsors Committee of Mr. Charles Francis Adams of the Raytheon Company. He commented on the valuable service of this committee to the Association in the solicitation and encouragement of corporate gifts and requested the cooperation of directors in obtaining the services of other business leaders as members of the sponsors committee.

Technical Advisory Committee Report

11. Chairman T. Seddon Duke of the Technical Advisory Committee presented recommendations on behalf of the committee. The following action was taken:

a. (1) It was voted to amend the Regulations Governing Technical Committee Procedure by inserting a new paragraph 34 to read:

> Committee activities and reports shall be consonant with the objectives of the Association as stated in Article 2 of the Articles of Association and shall not deal with unrelated subjects.

(2) It was voted to amend paragraph 52 of the Regulations Governing Technical Committee Procedure to require that reports proposing new standards or amendments to existing standards shall be received by the General Manager by March 1, complete with vote statement for advance publication, instead of March 15 provided heretofore.

(3) Paragraph 63 of the Regulations Governing Technical Committee Procedure was amended to read as follows:

> Voting by proxy at meetings of a Committee shall not be permitted. Any member of a Committee may send a representative to express his views in the deliberations of the Committee but the representative shall not have voting privileges unless this has been accorded to him by the Committee prior to the action.

(4) Paragraph 64 of the Regulations Governing Technical Committee Procedure was amended to read as follows:

> Any member (as defined in Article 3a. of the Articles of Association) represented on a Committee may request appointment of an alternate or alternates who shall have the privilege

of attending meetings in the absence of the regular representative and to vote in his stead. Such alternate or alternates shall be subject to approval by the Board of Directors in the same manner as regular representatives.

b. It was voted to clarify the sectional committee character of our Committees on Aviation and Marine Fire Protection by eliminating the designations "Executive Division" and "General Committee" and by designating as "Sectional Committees" the several committees now reporting to the Association through the Committee on Marine Fire Protection.

c. The staff was authorized to call a conference of those interested in the subject of fire reporting in order to investigate the desirability of establishing an NFPA Committee on Fire Reporting.

d. It was voted to establish a new Sectional Committee on Protective Equipment for Fire Fighters to report to the Association through the Committee on Fire Department Equipment. The following scope statement was approved:

To develop recommendations on protective clothing, respiratory protective equipment, and resuscitation methods and equipment for the purpose of providing guidance to the fire service on the selection and use of same.

e. It was voted to establish a new Sectional Committee on Rocket Propellants to report to the Association through the Committee on Chemicals and Explosives. The following scope statement was approved with the understanding that the committee might wish to suggest amendments thereto following its organization and examination of the problem:

To develop data and recommendations on rocket propellants pertaining to their fire hazard properties, techniques for fire control, and the prevention of fires and explosions in situations where these propellants may be involved or exposed.

f. It was voted to subdivide the Committee on Motor Craft and Marinas into two sectional committees to report to the Association through the Committee on Marine Fire Protection. One of the sectional committees, the Sectional Committee on Motor Craft, would operate under the following scope statement:

To develop standards on fire prevention and protection of motor craft and to encourage their use by designers, builders, and owners.

The second sectional committee, known as the Sectional Committee on Marinas and Boatyards, would operate under the following scope statement:

To develop standards on fire prevention and protection in the operation of marinas and boatyards.

g. It was voted to instruct the Committee on Gases and the Committee on Trailers and Trailer Courts to make further and vigorous efforts to resolve the existing differences between NFPA Standard No. 58 and NFPA Standard No. 501B.

Committee Appointments

12. Numerous appointments to technical committees recommended by the Technical Advisory Committee and other appointments to nontechnical committees were confirmed. The Technical Advisory Committee was authorized to act on other committee appointments prior to publication of the 1961–62 Year Book subject to confirmation by the Board at its next meeting. All other committee members were appointed for the year 1961–62 with the exception of those who have died, resigned, or have been dropped. (The 1961–62 Year Book will include a complete roster of committee personnel.)

Other Business

13. Proposed revision of paragraph 321 of the Standard for Dehydrators and Dryers for Agricultural Products (NFPA No 93) as submitted by the Committee on Dehydrators and Dryers, pursuant to action of the annual meeting, was discussed and approved.

14. It was voted to hold the next meeting of the Board at the Union League Club in New York on Thursday, January 25, 1962.

15a. Mr. Tryon reported that forty-eight new standards resulting from action of the annual meeting at Detroit were in process of publication, together with ten tentative standards. He discussed the magnitude of the printing operation now under way and the economic factors relating thereto.

b. Mr. Bond commented briefly on the forthcoming "Summer Study" on fire being conducted during July and August under the auspices of the National Academy of Sciences–National Research Council Fire Research Committee. The role of NFPA with respect to fire research was discussed by various members of the Board.

c. Mr. Bugbee reported on current membership promotion efforts by the staff involving the services of a consultant and the employment of revised direct-mail techniques. He also commented on the recent conflagration at Ayer, Massachusetts, and plans for carrying on a long-range analysis and reporting of the direct and indirect consequences of this loss.

Pressure Tanks for Sprinkler Installations

By H. Hoyle, M.I.E.E., M.I.Mech.E.

Mather & Platt Limited, Manchester, England

The world's annual fire loss is far too high. In 1960, in Great Britain alone, it amounted to about £44,000,000 ($123,000,000), an average per capita cost of $2.5. This fire loss could be reduced by the wider application of sprinkler protection. Yet many premises remain unprotected by sprinklers on account of the high cost or the impracticability of providing water at a rate of several hundreds of gallons per minute for a long period of time.

Statistical evidence of fires in sprinklered premises clearly indicates the high value of a pressure tank as a single water supply and calls for its more widespread recognition by the authorities having jurisdiction.

Presented at the 65th NFPA Annual Meeting, Detroit, Mich., May 15–19, 1961.

The primary objects of an automatic sprinkler installation are to detect an outbreak of fire and then to extinguish it by water discharged in suitable form over the location of the fire.

In the initial stages of extinguishment, the rate or density of application of water is of great importance. At the time of the detection of the fire and the opening of the sprinkler, the gaseous products of combustion are at a high temperature. The surface temperature of the burning material is high and other combustibles in the vicinity have been subjected to heating by conduction and radiation.

The maximum rate of cooling by water discharged from a sprinkler must therefore be achieved initially. Subsequently the rate of cooling can be less,

TABLE 1

Minimum Air Pressure Required in Pressure Tanks

Proportion of air in tank	Highest sprinkler above tank base — feet	Pounds per square inch						
		U. S. A. and Canada (NFPA)*	Great Britain† India Pakistan	France	Germany	Sweden	Denmark	Norway Finland
One third	0	75	75	71	92	71	78	74
	20	101	105	97	118	106	108	104
One half	0	45	45	43	57	43	50	45
	20	62	65	60	74	64	71	67
	40	80	85	77	92	86	93	89
	60	97	105	95	109	108	115	111
Two thirds	0	30	30	28	39	28	36	30
	20	43	45	41	52	46	49	43
	40	56	60	54	65	63	62	56
	60	69	75	67	78	80	75	69

*NFPA Standard for the Installation of Sprinkler Systems (No. 13).

†Home and Foreign Rules of the Fire Offices' Committee.

NOTE: Close similarity is shown in the minimum required air pressure.

TABLE 2

Minimum Static Pressure at Highest Sprinkler

Proportion of air in tank	Highest sprinkler above tank base, feet	Pounds per square inch						
		U. S. A. and Canada (NFPA)*	Great Britain† India Pakistan	France	Germany	Sweden	Denmark	Norway Finland
One third	0	75	75	71	92	71	78	74
	20	92	96	88	110	97	100	96
One half	0	45	45	43	57	43	50	45
	20	54	56	51	66	56	63	58
	40	62	68	60	74	69	76	71
	60	71	79	69	83	82	89	84
Two thirds	0	30	30	28	39	28	36	30
	20	34	36	33	43	37	40	34
	40	39	43	37	48	46	44	39
	60	43	49	41	52	54	49	43

*NFPA Standard for the Installation of Sprinkler Systems (No. 13).

†Home and Foreign Rules of the Fire Offices' Committee.

NOTE: Table 2 shows the minimum value of static water pressure at the highest sprinkler required by the respective rules, with the highest sprinkler level with the base of the tank and 20, 40, and 60 feet above it.

provided it is greater than the rate of heat generation to achieve extinguishment.

A pressure tank provides a water supply which meets these conditions. It exerts its maximum water pressure when in its normal standing charged condition; the rate of discharge of water from a sprinkler is therefore highest at the moment it opens. The pressure tank afterwards continues to provide water at an adequate, though falling, pressure.

The pressure required at the highest sprinkler is laid down in the rules and standards to which pressure tanks in several countries conform. Table 1 shows the minimum value of air pressure (hence water pressure) according to the proportion by volume of the air required for tanks supplying sprinklers at given heights above the tank base.

Air Pressures

Higher air pressure than the minimum values specified by the various rules are desirable to obtain the best sprinkler performance; this applies particularly to tanks containing the greater proportion of air.

Modern practice in Great Britain is to construct a pressure tank for a working pressure of 120 pounds per square inch (psi) and to charge it to this pressure, provided it is higher than the minimum value required by the rules.

In Europe the majority of pressure tanks have been installed at or about ground level, possibly because of a later application of sprinkler protection to premises already built.

Where new and higher buildings are equipped to carry a pressure tank higher than ground level, the practice is to charge the tank with air to a value above the minimum pressure required by the rules, yet ensure that the water pressure at the installation-controlling valves, or at the lowest sprinklers as the case may be, does not exceed 150 psi. If, however, there are any sprinklers above tank base level, they must be taken into account when deciding the working pressure of the tank.

TABLE 3

Minimum Quantity of Water in Pressure Tanks

(All Quantities Given in U. S. Gallons)

	Light hazard* or category 1	Ordinary hazard* or category 2	Extra hazard* or category 3	All cases	Notes
U. S. A. and Canada (NFPA)†	2000				Wet or dry
		3000			Wet system
		3750			Dry system
Great Britain‡				4000	
Australia	2400			4000	Special cases subject to authority having jurisdiction
France				3965	
Germany				3965	
Finland				3965	
Norway				3965	
Denmark	2115	2376	3168		
Sweden	2376	2376	3168		Not more than 50 sprinklers in communication
	2376	3168			50–100 sprinklers in communication
	3168	3168			More than 100 sprinklers in communication
			3965		More than 50 sprinklers in communication

*Occupancies within hazard classifications are similar but not identical for the various countries.

†NFPA Standard for the Installation of Sprinkler Systems (No. 13).

‡Home and Foreign Rules of the Fire Offices' Committee.

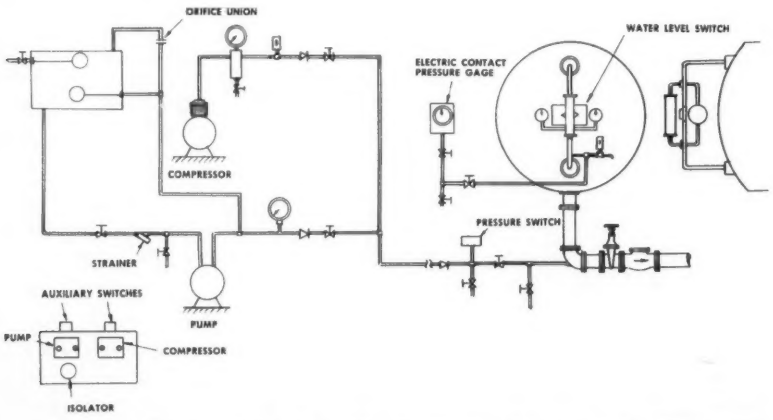


Figure 1. Arrangement of equipment for the charging of pressure tanks automatically with water and compressed air. When the water level falls by more than ½ inch, the float switch causes the pump to run until the correct level is reached. If the air pressure falls due to leakage, the electric contact pressure gage causes the compressor to run until the correct pressure is reached. The air compressor cannot run until the water level is correct.

Water Requirements

The amount of stored water required in a pressure tank according to the rules of various countries, is shown in Table 3.

Where there is no occupancy limitation the general requirement is about 4,000* gallons. Where the number of sprinklers is limited, and under certain conditions of occupancy, the quantity of water may sometimes be halved — a minimum of 2,000 gallons.

Charging of Pressure Tanks

To provide an effective water supply to a sprinkler installation, a pressure tank needs to be maintained charged with the requisite amount of water and air pressure.

The NFPA and French rules call for automatic maintenance of air pressure and for a low water alarm where the pressure tank provides the sole supply to a sprinkler installation.

In contrast to this, although not required to do so by any rules, one British company provides fully automatic equipment for the maintenance of both water level and air pressure in the pressure tank even if it is only one of the water supplies provided. This arrangement is shown diagrammatically in Figure 1.

A water level float switch and pressure gage with electric contacts controls the running of the water pump and air compressor. When the water level falls by more than ½ inch the float switch causes the pump to run until the correct working level is reached; if the air pressure falls due to a leakage, the electric contact pressure gage causes the compressor to run until the correct working pressure is reached. The air compressor cannot operate automatically until the water level is correct.

For use when it may be required, means are provided for manual operation of the switchgear for the pump and compressor. The schematic arrangement of electrical connections is shown in Figure 2.

There are some water authorities in Great Britain who do not permit water to be run into a cistern from which it can be drawn to charge a pressure tank. They require the pump to operate as a booster with its suction branch directly connected to the supply main. Wide variations of the pressure in the supply main, and the possibility that the pressure in the main will at times exceed the working pressure of the pressure tank, preclude the use of automatic control of the charging equipment and under these circumstances only manual switching is provided for the pump and the compressor.

The diagrammatic arrangement of the apparatus is shown in Figure 3.

Dry Sprinkler Installations

It is only the NFPA Standard that calls for additional water in the pressure tank, sufficient to fill the pipework of a dry pipe system. The maximum pipework capacity specified is 750 gallons and this quantity is to be added to the 3,000 gallons minimum quantity in the pressure tank (for ordinary occupancies).

On the other hand, the rules of the Fire Offices' Committee require a minimum of 4,000 gallons of water in the tank but permit 700 sprinklers on a dry system. The pipework capacity would amount to about 900 gallons on a basis of 1.3 gallons per sprinkler, and this deducted from the 4,000 gallons minimum required in the pressure tank leaves 3,100 gallons net for any occupancy as

*Throughout this paper quantities of water are given in U. S. gallons.

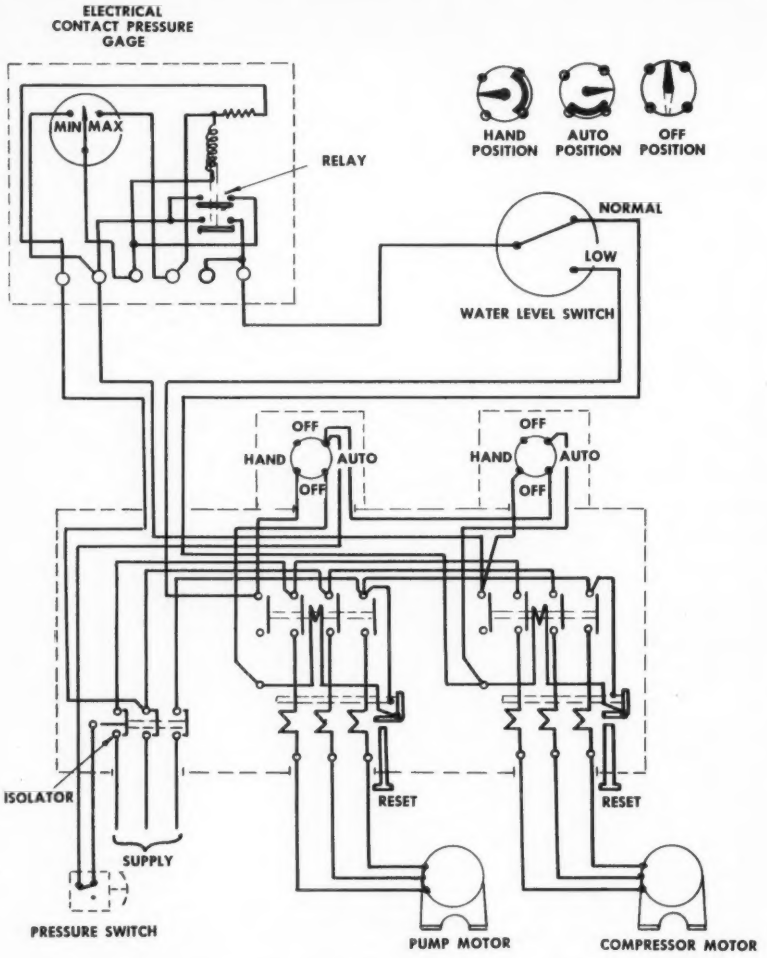


Figure 2. Electrical connections for automatic pressure tank charging equipment. As shown near the upper right of the diagram, the water level switch is in the "normal" correct water level position. If the water level is low, the switch changes to the "low" position. Auxiliary switches near middle of diagram permit manual control of compressor or pump if desired.

The pressure switch, in lower left of diagram, is operative to stop the pump or compressor, irrespective of the charging being automatically or manually controlled.

against the minimum NFPA net requirement of 3,000 gallons for an ordinary occupancy.

The quantity of water which enters a dry pipe system when the air valve trips because of the opening of one or only a few sprinklers, is, however, much less than that required to fill the pipework. A considerable amount of air is trapped in the pipework and is

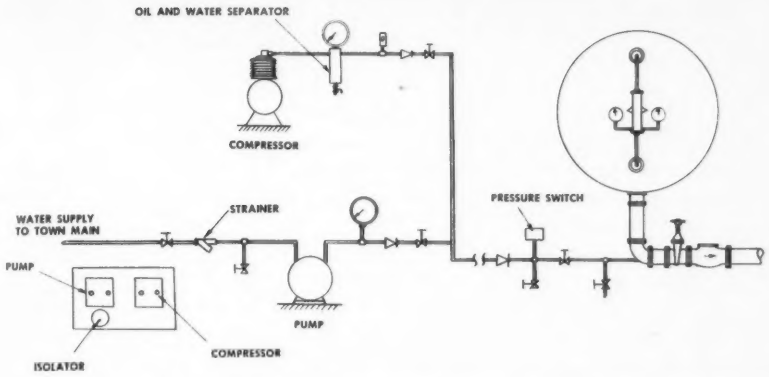


Figure 3. Pressure tank charging equipment — nonautomatic. The pressure switch will stop the motor or compressor should they be left running and the pressure in the tank be raised above 15 psi plus the working pressure.

further compressed by the higher pressure water entering the installation.

One factor governing the amount of water required to charge the sprinkler pipework, when the air valve trips, is the air pressure to which the pipework is charged. The higher the initial air pressure, the greater the quantity of trapped air and hence the less the amount of water needed to charge the pipework.

It is of advantage to maintain a reasonably high air pressure in the sprinkler pipework, and to employ an accelerator. This brings about the opening of the air valve before the installation pipework air pressure has fallen to a value low enough to allow the air valve to trip.

Not all the water with which the pipework becomes charged is "lost." Quite a large proportion of it can become effective for discharge from the opened sprinklers especially when an efficient accelerator is provided.

The maximum number of sprinklers allowed on an installation with or without an accelerator is given in Table 4.

TABLE 4

The Maximum Number of Sprinklers Allowed on a Dry Installation

	Without accelerator	With accelerator	Irrespective
U. S. A. and Canada (NFPA)			600
Great Britain*			700
Australia			700
Pakistan			700
Finland	700	1000	
Norway	700	1000	
Denmark	500	1000	
Sweden	500	1000	
Germany	500	1000	
France	300	700	

*Home and Foreign Rules of the Fire Offices' Committee.

As the pressure in the tank falls with discharge of water from the sprinkler, the "trapped" air in the pipework which has been further compressed by the entry of higher pressure water from the pressure tank expands to drive the water in the pipes in the direction of the opened sprinklers.

The amount of water which remains effective depends on the type of build-

ing and the position of the sprinkler or sprinklers caused to open by the fire.

In the case of a multistoried building and a fire at ground level, the quantity of compressed air lost through the opened sprinklers is small, and as much as 75 per cent of the water with which the sprinkler pipework is initially charged when the air valve trips can be effective for discharge from the sprinklers.

Under other conditions, in a single-story building, for example, the effective percentage could be less, especially where the open sprinklers are situated near the terminus of the installation.

Value of a Pressure Tank Water Supply

To assess the value of a pressure tank water supply, the evidence of statistics of fires in which sprinklers have operated can be examined.

The postwar record of one British company for all classes of occupancy is shown in Table 5.

TABLE 5
Pressure Tank Sprinkler Performance Record in 872 Fires

(Postwar Record of Installations of One British Sprinkler Company)

Number of sprinklers operating	Wet system Per cent	Dry system Per cent	Total Per cent
1	39.97	32.11	38.74
2 or less	56.77	46.71	55.20
3 or less	65.04	59.12	64.11
4 or less	71.00	62.04	69.60
5 or less	74.25	65.69	72.91
6 or less	77.50	67.88	76.00
7 or less	80.35	70.07	78.74
8 or less	82.65	73.72	81.25
9 or less	84.28	75.91	82.97
10 or less	85.09	76.64	83.77
11 or less	85.63	78.10	85.14
12 or less	88.61	82.48	87.65
13 or less	88.88	83.21	88.00
14 or less	90.24	83.94	89.25
15 or less	90.51	86.13	89.82
18 or less	91.59	88.32	91.08
20 or less	93.08	88.32	92.34
25 or less	94.03	91.24	93.60
30 or less	95.66	94.16	95.42
35 or less	96.88	95.62	96.68
40 or less	97.69	97.08	97.60
50 or less	98.50	97.81	98.40
75 or less	99.59	100	99.65

TABLE 6
Pressure Tank Sprinkler Performance — Two Supply System

Number of fires dealt with by water from pressure tank only.

(1935-1960 Record of Installations of One British Company)

Number of sprinklers operating	OCCUPANCY Light Hazard	Ordinary Hazard	Extra Hazard	Cumulative Total Per cent*
1	1	167	9	38.4
2	...	73	7	55.7
3	...	25	5	62.2
4	...	24	...	67.5
5	...	14	...	70.5
6	...	11	3	73.5
7	...	10	4	76.6
8	...	7	...	78.1
9	...	6	1	79.6
10	...	4	...	80.5
11	...	3	2	81.6
12	...	6	1	83.1
13	...	1	...	83.3
14	...	2	...	83.7
15	...	1	...	83.9
16	...	1	...	84.2
17	...	...	...	84.2
18	...	...	...	84.2
19	...	...	...	84.2
20	...	...	1	84.4
Total fires	1	355	33	

*Percentages are of the 461 cases in which the pressure tank provided the primary or higher pressure water supply. In 72 of these fires, water from a secondary supply was also used.

The total number of fires reported during this period is 872, and Table 5 shows that 83.8 per cent of the fires caused 10 or less sprinklers to open, and 92.3 per cent caused 20 or less sprinklers to open.

Fire incidents which cause only a few sprinklers to open are often considered to be of insufficient interest to warrant a report. The view is taken that the sprinkler protection has simply done its job, as it was expected to do, so why should this be reported? If all such incidents were reported an even greater efficiency of sprinkler performance could be shown.

Pressure Tank as Primary Supply

Since 1935 there have been 515 fires on premises in Great Britain which have

a pressure tank as one of the water supplies to the sprinkler protection installed by this same company. In 461 cases, the pressure tank has provided the primary or higher pressure water supply, and the detailed fire reports show that 389 (i.e., 84.4 per cent) of these fires were dealt with by water from the pressure tank alone.

An analysis of the 389 fires dealt with by water from the pressure tank showing the number of sprinklers which opened and the type of occupancy of the premises, generally as defined by the NFPA, is shown in Table 6.

Limited Recognition of Systems

Some authorities appreciative of its value recognize automatic sprinkler protection with a single water supply from a pressure tank.

U. S. A. and Canada

The NFPA Standard for the Installation of Sprinkler Systems (No. 13) contains the generally accepted installation rules for pressure tank sprinkler system installations. A pressure tank may be acceptable as a single water supply in some cases but these are not defined.

France

Sprinkler installations are to comply with the Rules of the Assemblée Plénière des Sociétés d'Assurances contre l'Incendie, and a pressure tank is acceptable as a single water supply for such occupancies as:

(a) flour mills for wheat and similar products
(b) biscuits, macaroni
(c) bleaching, dyeing, and printing
(d) haberdashery, clothing manufacture, underclothing
(e) printing, paper and box making
(f) garages
(g) drawing offices and studios
(h) preparation of hides, leatherworking
(i) shoe factories
(j) metal working shops.

Subject to the following conditions:

1. Maximum number of sprinklers on installations, 500

2. Maximum number of sprinklers in communication, 115

3. Minimum quantity of water in pressure tank, 3965 gallons

TABLE 7

Air Pressure Required in Pressure Tanks — French Rules

Proportion of air in tank, Per cent	Air pressure allowed in tank when the base is level with the highest sprinkler		Pressure to be added for each foot when the tank is below the highest sprinkler	Maximum permissible height of highest sprinkler above pressure tank
	Max. psi	Min.* psi	psi	Feet
33⅓	114	71.1	1.300	33
50	114	42.7	.867	82
57.1	114	35.6	.780	98
62½	114	31.3	.694	115
66⅔	114	28.5	.650	131

*Minimum standing pressure at the highest sprinkler is that given in this column. Where sprinklers are at a higher level than the base of the tank the standing pressure is higher than the values in this column.

4. Air compressor must start automatically when the air pressure falls

5. Low water level alarm must be provided

6. Minimum air pressure in tank to comply with Table 7.

Ceylon and East Africa

The Ceylon Fire Insurance Company and also the East African Insurance Association accept a pressure tank as a single water supply for tea factories under certain conditions.

1. The pressure tank must conform to the British Fire Offices' Committee (Foreign Rules) for Sprinkler Installations.

2. Sprinklers in the withering lofts shall have ¼-inch-diameter orifices, be fitted with efficient sieves, spaced not more than 10 feet apart with at least 1 sprinkler per 50 square feet. The positions of the sprinklers in relation to the banks of tea tats and gangways is laid down. Pipe sizes smaller than standard are permitted.

3. Sprinklers, other than those in the withering lofts, shall have ½-inch-diameter orifices and there shall be at least one sprinkler per 100 square feet of floor area.

A pressure tank also is accepted as a single water supply to sprinklers in cotton ginneries by the East African Insurance Association. In brief, the requirements are:

1. The pressure tank must be of 12,000 gallons capacity, with 6,000 gallons of water, and be charged with compressed air to a pressure not less than 100 psi.

2. The sprinklers (½-inch-diameter orifices) are to be not more than 8 feet apart and there must be at least 1 sprinkler to each 64 square feet floor area.

Australia

A special provision is made under which a pressure tank would be acceptable as a single water supply for a light hazard occupancy provided that the conditions are favorable to such an arrangement.

The quantity of water required to be stored in the tank is a minimum of 2,400 gallons, with minimum air pressure according to the Foreign Rules of the Fire Offices' Committee. The minimum standing pressure at any sprinkler will be 30 psi.

Conclusion

Such limited recognition of the pressure tank for a single water supply sprinkler installation is unjustified in the light of available evidence of its value. Recognition by the responsible authorities would lead to the adoption of automatic sprinklers for many premises which will otherwise remain unprotected and subjected to the menace of fire.

Three Service Station Explosions

Auburn, N. Y., March 30, 1960*

A remodeled 30-ft. by 40-ft. one-story cinder block service station building with basement was demolished by a violent explosion originating in the basement area. Three firemen and two service station employees who were in the basement of the building at the time of the explosion were killed.

The fire department had been called at 7:30 P.M. to investigate a report of gasoline vapors in the service station building. Gasoline was found floating on water that had accumulated in the basement due to rapidly melting snow. The firemen had laid a hose line to the basement of the building, and one member of the four-man engine company had been sent back to the fire apparatus for a hose holder when the explosion occurred.

A gasoline tank located adjacent to the building was a possible source of the gasoline in the basement. This tank had been abandoned two years previously after an investigation of the

*The information in this report was obtained by an investigation of the explosion by Miles E. Woodworth, NFPA Flammable Liquids Field Service Specialist.

H. G. Tasby

Gasoline service station, Auburn, N. Y. Three firemen and two employees were killed when an explosion demolished the one-story building that formerly stood on this site. Source of gasoline in the basement was being investigated when the explosion occurred.

Front Royal Fire Department

Gasoline service station, Front Royal, Va. Four occupants of this station were hospitalized by an explosion that occurred shortly after a mixture of gasoline and kerosene had been used to clean the grease stall and pit.

reason for water in the tank revealed that it was leaking. However, recommended procedures to be followed when underground tanks are to be abandoned in place were not followed. These procedures, spelled out in the NFPA Recommended Procedure for the Abandonment or Removal of Service Station Underground Tanks (No. 30F), include, among others, removal of all flammable liquid, disconnection of all lines, and filling the tank with an inert, solid material. No. 30F is published as an Appendix to the Flammable Liquids Code, NFPA No. 30, and is included in Volume I of the National Fire Codes.

Front Royal, Va., March 5, 1961*

An explosion in a gasoline service station in Front Royal injured the four occupants of the station and caused extensive structural damage. The ensuing fire completed destruction of the building and its contents.

The one-story brick, wood-joisted station consisted of a first floor with salesroom, rest rooms, office, grease stall, and wash stall. A partial basement contained storage rooms and a grease pit. The grease pit communicated with the storerooms through doors. The storerooms contained tires, batteries, the air compressor, and other equipment.

It was a sunny Sunday afternoon with the temperature in the low 70's. Four persons were in the station, including three employees ages 22, 21, and 17, and a 16-year-old visitor. About 2:45 P.M. they started to wash down the grease stall and pit with a mixture of gasoline and kerosene. After they completed the washdown, they placed a bucket with about one gallon of the mixture in it near the door to the salesroom. The

*Based on detailed information supplied by C. Warren Turner, Chief of the Front Royal Volunteer Fire Department.

stall and pit were then hosed down with water. The overhead doors to the stalls had been open all during the cleaning and washdown operation and remained open.

During the cleaning operation, flammable liquid vapors spread into the basement storage area where they formed an explosive mixture. At 3:17 P.M., an explosion knocked out a rear wall and part of a side wall, scattering glass and other debris up to 150 feet away. The air compressor motor in the basement is thought to have supplied the igniting spark. The occupants were thrown to the floor but managed to get out before the fire became intense. They report the flames as first starting in the grease pit itself and quickly spreading to the entire building.

Fire fighters that responded to the telephoned alarm found that the injured had been removed to the hospital by a passing motorist and that the building was now fully involved. Two 1½-inch preconnected fog lines and two 1-inch booster lines were used to control and extinguish this fire. These four lines were supplied by the pumper's 500-gallon booster tank while a 100-foot, 2½-inch supply line was being laid to a nearby hydrant. A 2½-inch line with a 240-gpm fog and straight stream nozzle was laid to back up the smaller lines but was never used.

Philadelphia, Pa., April 15, 1961*

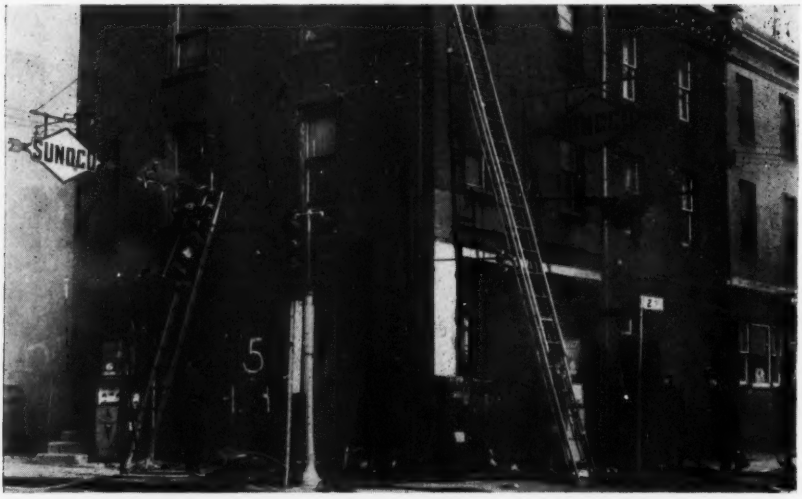
A violent explosion in a 3-story brick, wood-joisted gasoline service station building killed three firemen and injured 26 persons. The building was destroyed. According to the Philadelphia Fire Department the explosion occurred in the basement and involved gasoline vapors.

This service station was of a type which is no longer permitted in Philadelphia but under the "grandfather" clause of the Fire Prevention Code was permitted to continue operations. The gasoline dispensers were located on the sidewalk against the building with pipe stanchions on the curb supporting the hose and nozzle for making deliveries to automobiles in the street (see upper photo, page 88). One of the tanks (1,080 gallons capacity) was located under the basement floor at a lower level than were three additional tanks on adjacent property. A common fill pipe supplied all tanks.

Approximately three weeks before the explosion, a maintenance company was called on a complaint that water was in the tank under the basement floor. When workmen broke through the concrete floor to locate the gage riser, water seeped into the basement. This water had to be pumped out before the cap on the gage riser could be removed. A test was made and the tank declared free of water. The break in the floor was repaired with concrete.

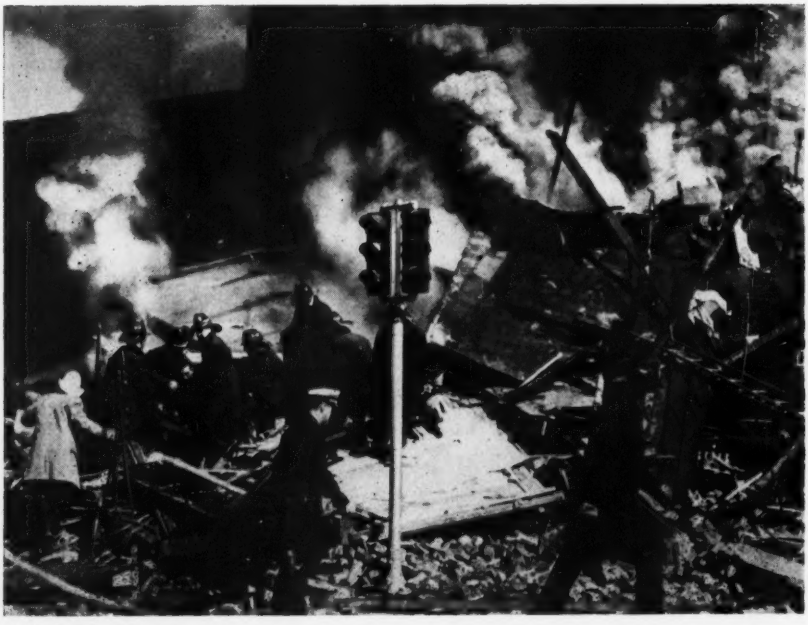
On the day before the explosion, two complaints were received from customers about water in their automobile tanks. The presence of water in the tanks was confirmed by the supplier of the gasoline, and again the maintenance company was called. Upon the arrival of two of the maintenance company employees, there was no odor of gasoline but they found about half the basement covered with water up to a depth of 1½ inches. Knowing the location of the gage riser from their previous visit, they broke through the concrete. Additional water seepage resulted. Since the cap of the riser was under water, they could not remove it and were told by their

*This account is based on a report of investigation submitted by the Philadelphia Fire Department. The oil company which supplied the station does not concur with the results of the Fire Department's investigation.



Philadelphia Fire Department

Gasoline service station, Philadelphia, Pa. These two photos were taken about four minutes apart. The upper shows conditions as first arriving fire companies were ventilating and running lines; the lower was taken immediately after the explosion as efforts are made to rescue those trapped. Three fire fighters were killed and 26 fire fighters and spectators were injured.



Philadelphia Fire Department

company to leave it as it was until the next morning.

On Saturday morning (April 15) a mechanic from the maintenance company arrived to find several inches of water in the basement. The oil company tank vehicle had just completed a delivery and was still there. After finding the water in the basement, the mechanic went back to his truck to get boots and a pump. Upon returning to the basement he saw fire start at a gas-fired hot water heater. The fire burned on a portion of the water and up the wall near the heater. The mechanic ran through the fire and alerted the station attendant and the tank truck driver. He then ran to the fire station nearby and gave the alarm. Fire department response was immediate.

The first firemen to arrive found heavy black smoke and fire visible on the first floor. Ventilation of the building was started, and two hose lines were laid. One was taken into the first floor, and the second line was taken into the basement, using the exterior cellar stairs. The firemen who entered the basement did not smell any gasoline vapors nor could they see any fire, although the basement was filled with smoke. It was then that an explosion of low order magnitude occurred, which knocked one of the firemen to the floor, and flames appeared in the rear of the basement.

The two firemen left the basement, but one returned several minutes later and noticed a strong odor of gasoline. At this time there were no flames visible, although the smoke was extremely dense. In a few minutes he left the basement, and water lines were directed into the cellar from outside the building. Shortly thereafter, a violent explosion occurred which demolished the building.

Two of the firemen who were killed were trapped inside the demolished building, and the third was hit by flying debris. Twenty-six spectators and fire fighters were injured by flying debris

The tank under the building was subsequently excavated and tested for leaks. Two leaks were discovered, one near the bottom of the tank on the head-to-shell seam and the other a jagged, approximately ½-inch hole at the top center of the tank. When excavated, the tank was full of water.

The Philadelphia Fire Department concluded that gasoline vapors from the leaking tank were ignited by the pilot light of the gas-fired hot water heater in the basement, triggering the explosions which resulted in the destruction of the building.

Chemical Plant Waste Incinerator

By Charles L. Sercu, Manager

Waste Control and Utilization, Midland Division
The Dow Chemical Company, Midland, Michigan

A two million dollar incinerator plant was put in operation in January 1959 to destroy safely and efficiently all types of burnable wastes from the Midland, Michigan, Division of The Dow Chemical Company. The project includes a rotary kiln type refuse incinerator, a liquid tar furnace, acid gas scrubbers, and handling and storage facilities for solid and liquid wastes.

This equipment was necessary because of the large quantities of wastes requiring safe destruction with a minimum of air and water pollution.

Liquid Waste Disposal

At the Midland plant, between 250 and 300 portable tank loads of tar are produced per week, representing more than 600,000 gallons per month of still residues, waste solvents, wastes, and contaminated products to be destroyed.

These tars vary in flammability and viscosity, and several are reactive with other tars. In addition, more than 400 drums of all sorts of burnable hydrocarbons are hauled to the incinerator area for disposal each month.

Delivery to Incinerator

All requests for hauling wastes are telephoned to the incinerator office. Any request involving materials for which procedures have not been established is turned over to the supervisor, who then checks with those who produced the strange material, to determine handling precautions and burnability. If necessary, special handling and disposal techniques are set up. A dispatch slip with all the necessary data is then prepared, and the information is radioed to a pick-up truck.

When the truck gets to the incinerator, the driver stops at a microphone and calls out the specific tar by the number of the building where it originated. Loud speakers carry the message to the operating areas. Using the public address system, the clerk assigns the load to a specific tank. Everyone in the area is thus alerted to the waste and knows which tank will be used (see photo 1).

An electric eye in front of the tar tanks actuates a series of bells when a truck backs in to dump. Everyone below is thereby warned to vacate that area to avoid possible injury were some dangerous chemical reaction to cause a boil-over.

Drums of liquid wastes are unloaded to a drum dock where the contents are drained to an agitating tank. Drums are grounded if necessary. These tars originate in over 120 production or laboratory areas. Some of these sources produce three or four different tars that cannot be mixed, so close control of the handling and dumping of these tars is an absolute and continuing necessity.

Based on an address by Mr. Sercu presented at the 65th Annual Meeting, May 15–19, 1961, at Detroit, Mich. Mr. Sercu illustrated his talk with slides and a motion picture.

There is always the danger of unhydrolyzed or reactive materials being present that might result in an explosion or fire.

Liquid Waste Storage Tanks

All tar storage tanks are numbered and used for specific wastes. Total holding capacity is 100,000 gallons. Two tanks receive only high Btu, low ash tars which can be sent to a powerhouse for burning as fuel.

Tanks near the drum docks are used for solvents and water slurries. There are insulated tanks for storing and blending "hot" phenolic tars at temperatures in excess of 175°F. All tanks are agitated, have large explosion vents, and are interconnected. All piping is steam traced and insulated.

Portable tanks in which unhydrolyzed or low flash point materials are brought to the incinerator, sometimes under a nitrogen atmosphere, are spotted near the tar incinerator so that they can be grounded and pumped directly to the burners.

Liquid Waste Disposal Furnace

Liquid wastes are destroyed by burning in a stationary rectangular furnace designed to operate at a rate of 81 million Btu per hour, or about seven gallons of liquid tars per minute. Products of combustion are vented to a stack or through scrubbers if they are high in acid content.

After being mixed and blended, the tars are screened and pumped to the

Photo 1. Liquid waste is dumped into storage tanks where it is agitated until piped to burners in the furnace. The method of disposal of each liquid waste is determined before it is delivered.

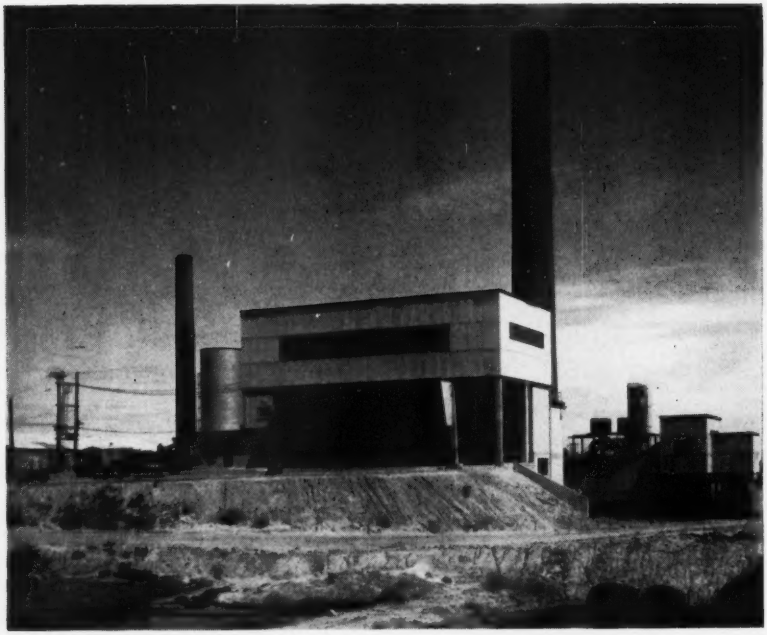


Photo 2. View of dumping area for solid refuse at the Midland, Michigan, Division of The Dow Chemical Company.

burners. These are low-pressure, air atomizing burners. When properly adjusted, combustion temperature can be maintained at 1,700°F, which is necessary to destroy all smoke and odors. Flame failure alarms and manual reset valves are standard equipment on this furnace.

Solid Waste Disposal

At the Dow plant at Midland, Michigan, incineration is the only practical method that has been found to dispose of major quantities of solid combustible wastes.

The solid refuse consists of the usual paper, boxes and packing cases, a small amount of garbage, and a large proportion of scrap plastic materials. Plastics may be as powder, granules, extruded or expanded shapes.

Delivery to the Incinerator

Six hundred portable metal bins of various sizes and designs are located throughout the Midland plant to facilitate collection and delivery of the solid wastes. During sixteen hours of each day, several trucks are assigned to haul these bins to the incinerator site where their contents are dumped into a receiving pit (see photo 2).

Plastic materials are delivered from experimental plants or production plants for disposal in various shapes and sizes. So that the incinerator feed equipment will not be fouled, the maximum length of pieces that can be burned is specified as is also the type and size of fiber con-

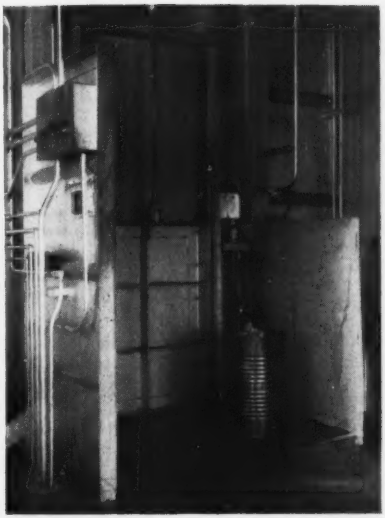


Photo 3. Arrangement for putting drums of potentially explosive materials in the incinerator. From behind the shield at left, hydraulic controls can be operated to raise the vertical sliding door in the feed chute and move the drum to the chute.

tainer that may be used for disposal of powdered or granulated wastes.

A crane operator spends about half of his time raising refuse to the charging hopper floor 60 feet above the bottom of the pit and the other half mixing the refuse in the pit to assure a uniform furnace feed.

Solid Waste Handling at the Incinerator

The receiving pit is 20 feet wide, 54 feet long, and 20 feet deep — an 800-cubic-yard refuse storage space.

About 500 cubic yards of refuse are received daily at the pit where it is mixed and stored until raised to an incinerator charging hopper.

Because of the hazardous nature of many of the waste chemicals, fires start easily in the storage pit. Heat detectors are located over the pit to actuate a horn, and spray nozzles, positioned around the pit, can be manually controlled from the operating floor. The spray nozzles can also be used to wet down highly combustible pit contents to reduce the rate of burning.

Solid Waste Disposal System

From the feed hopper the refuse drops to the feed conveyor which carries it to the feed chute where it drops down an incline to the kiln. The speed of the conveyor can be reduced to maintain proper combustion temperature when a high proportion of plastic is being fed. Manually operated spray nozzle protection is provided for the feed hopper and the conveyor.

A special arrangement has been developed to introduce drums or packs of potentially explosive materials into the kiln (see photo 3). To eliminate the danger to which employees would be subjected if they were to throw such a container down the open feed chute, the following procedure is followed. The conveyor is stopped, and a "drum grid" or platform is raised in the chute to a position opposite a guillotine-type door (vertical sliding) in a wall of the chute. From behind a metal shield an operator by remote control can raise the door and cause the drum to be moved through the doorway to the grid. After the door is closed, the grid lowers the drum to a sliding position in the feed chute and releases it.

To introduce very toxic or explosive wastes, there is a small hole in the floor above the feed chute. Explosion vents are placed in the chute and in the furnace to prevent damage by explosions.

The feed chute is water-cooled to remove absorbed radiant heat and prevent ignition of the chute itself. In addition, an ultraviolet flame detector is installed in the feed chute, and a manually controlled spray nozzle fire

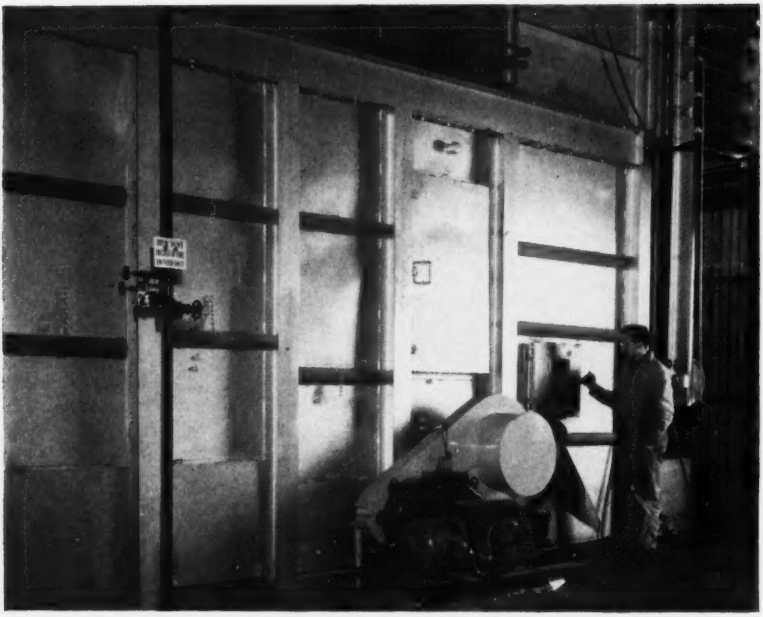


Photo 4. Feed chute enclosure. Note control valve for water spray fire extinguishing system. Observation port is in front of operator. The feed chute is water-cooled to remove heat absorbed from the kiln. A flame detector gives an alarm in case fire occurs in the chute.

extinguishing system has been installed in the chute (see photo 4).

Solid Waste Incinerator

A thorough study of incinerators indicated that a rotary kiln was the best type of equipment to use for the wastes at the Midland plant.

The rotary kiln is 13 feet in diameter and 35 feet long, lined with a nine-inch thickness of refractory brick.

The kiln is fully automatic and is enclosed for maximum protection. Sight glasses are provided to view the process, so that the operator may know at all times the type of material being burned.

Simple, yet adequate, instrumentation permits the operator to control the unit at all times. From a control panel (see photo 5), the operator adjusts the speed of the conveyor and the kiln, operates the master hydraulic controls, and regulates dampers and air supply centrifugal fans. Various temperature recorders and draft gages are mounted on the control panel.

Tar burners are installed to keep the kiln hot when there is no rubbish to burn. The burners are located on both sides of the feed chute, mounted in a seal plate. Each is equipped with a flame supervision device to shut off the flow of tar when no flame is detected. Light tars or waste solvents are usually burned as a pilot flame. The heavy tars are forced farther out into the kiln before combustion takes place. The effect of the high radiant heat on the feed chute and seal plate is thus minimized to some extent.

Photo 5. Control panel for solid waste incinerator. The incinerator feed chute is at right. Speed of the feed conveyor and of the rotary kiln, dampers, and air flow are controlled from this location.

Key to Safe Operation

The clerk is the first line of defense against unsafe operation at the incinerator plant. All disposal requests come to him, and it is he who must differentiate between routine acceptable wastes and problem wastes.

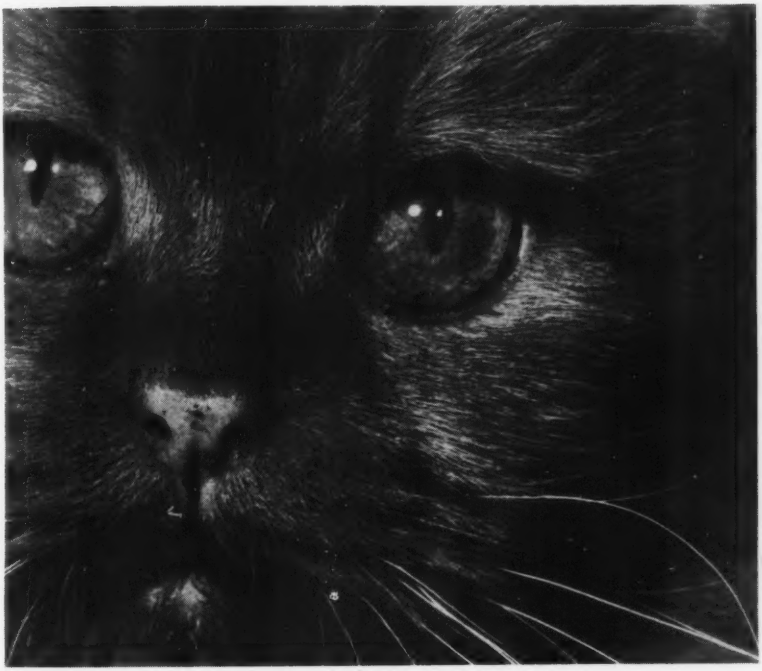
Problem wastes are referred to the incinerator supervisor for decisions on disposal methods. If printed information is not available, the safety department or the biochemical department may be consulted. The originator of the material at the plant or the manufacturer is often contracted for advice.

The decision may take hours to reach, but the key to the safe operation of the incinerator is the thoroughness with which all materials are investigated before they are accepted for disposal.

INDEX TO ADVERTISERS

July 1961

	Page
American District Telegraph Company (ADT)	A1
Ansul Chemical Company	A11
Armstrong Cork Company	A30, A31
Autocall Company	A12
"Automatic" Sprinkler Corporation of America	A32
Cardox, Division of Chemetron Corporation	*Inside Front Cover*
Celotex Corporation	A13
Central Station Electrical Protection Association	A18
Central Station Signals, Inc.	A8
Chicago Bridge & Iron Company	A9
Dusing & Hunt, Inc.	A19
El-Tec, Inc.	A17
Gamewell Company	*Inside Back Cover*
Grinnell Company	*Outside Back Cover*
Kelmore, Inc.	A27
Walter Kidde & Company, Inc.	A6, A23
Kinnear Manufacturing Company	A16
Kuhns Brothers Company	A24
M & H Valve and Fittings Company	A15
R. C. Mahon Company	A21
National Fire Protection Association	A10
National Foam System, Inc.	A28
Notifier Corporation	A29
Overly Manufacturing Company	A4, A5
Raisler Corporation, Raisler Sprinkler Division	A26
Reeve Electrical Company, Inc.	A2
Reliable Automatic Sprinkler Company, Inc.	A20
Rockwood Sprinkler Company	A3
Star Sprinkler Corporation	A25
Tokheim Corporation, General Products Division	A22
Van-Packer, Division of The Flintkote Company	A7
Viking Corporation	A14



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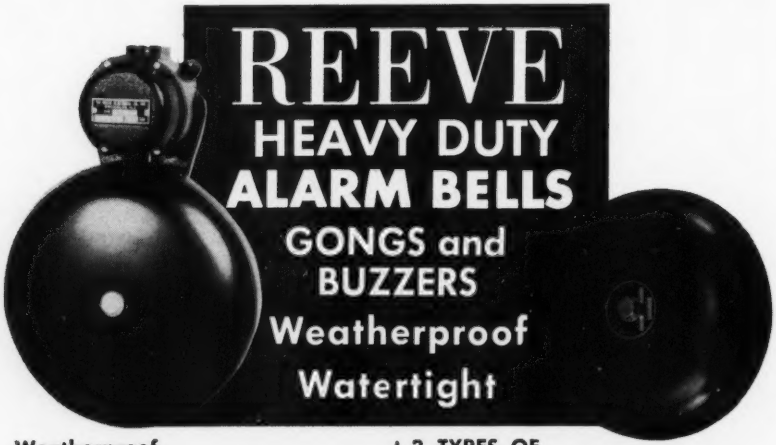

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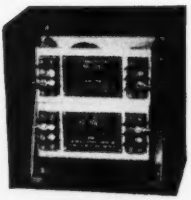

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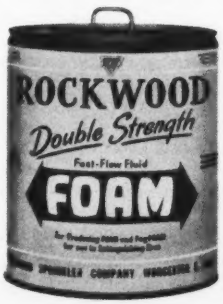

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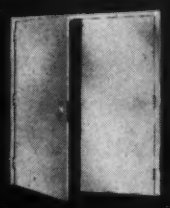

1957

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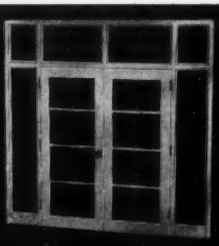

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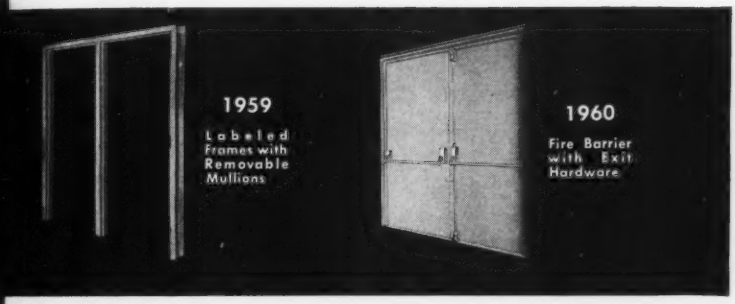

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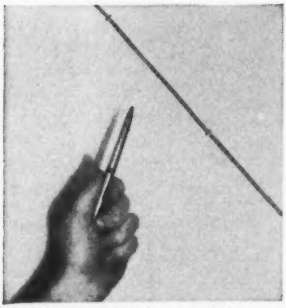

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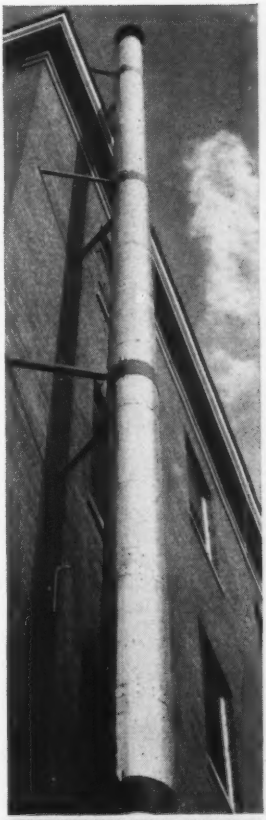

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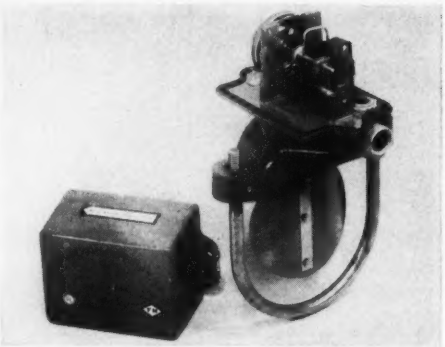

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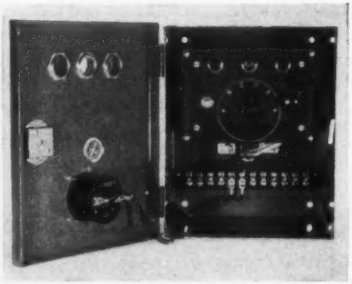

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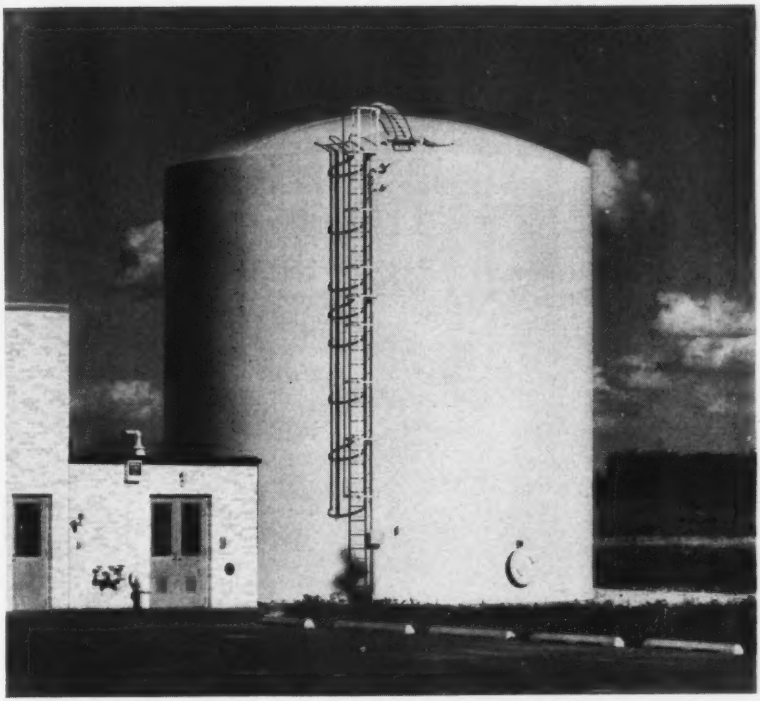

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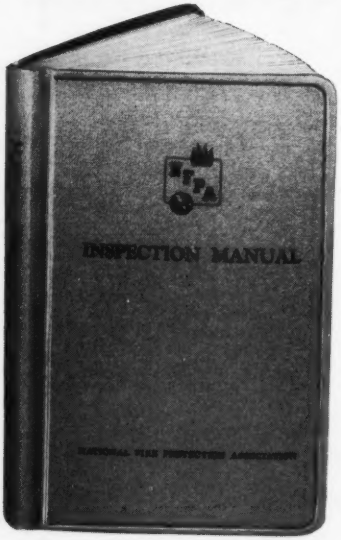

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IF YOU'VE BEEN WAITING FOR A RELIABLE

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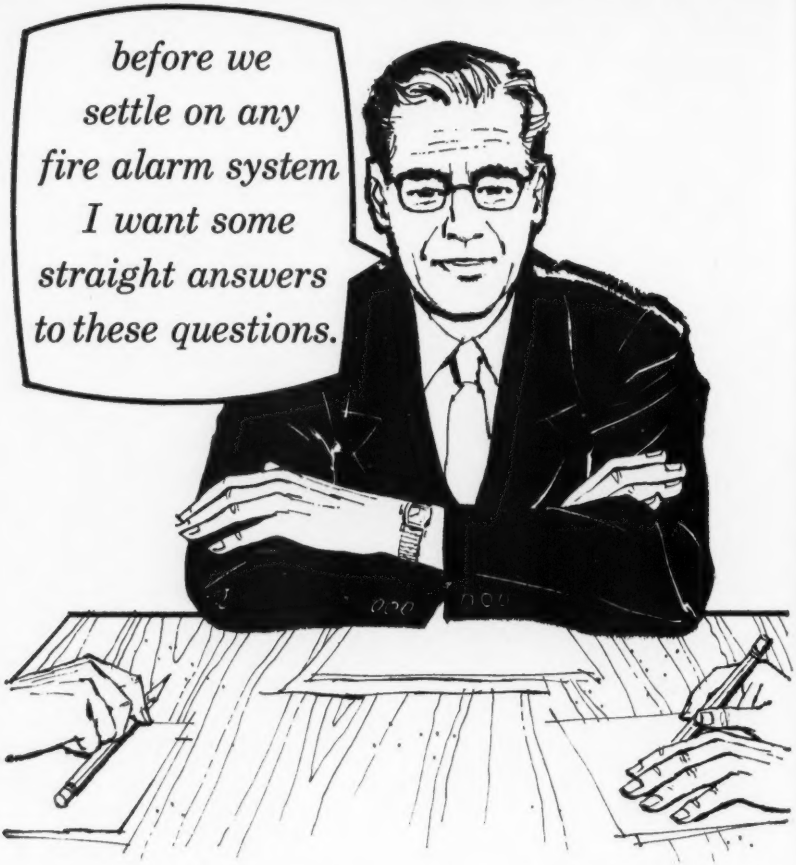
"FORAY" extinguishers (both cartridge and stored pressure) carry these Underwriters Laboratories ratings: Model 10: 1A-16B:C, Model 20: 3A-20B:C, Model 30: 4A-20B:C



- Will it automatically detect fires or does someone have to first see the fire or smell the smoke?
- Will it automatically sound the alarm or does someone have to pull a rope or lever to signal the danger?
- Will everyone be able to hear the signals in all parts of the building?
- Will the system automatically call the fire department, or must someone try to reach the fire station by phone?
- Will the fire alarm system automatically tell us (and the fire department) if and when it isn't working... or do we just assume we're still protected?

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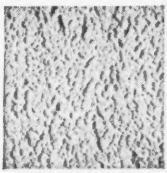
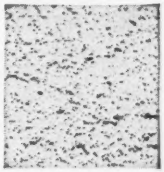
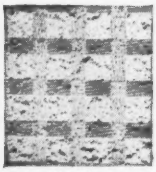


TEXTURE-TONE*



CELOTONE®



"DESIGN" CELOTONE® Plaid

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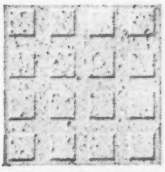
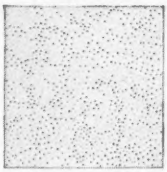


"DESIGN" CELOTONE® Empress

"DESIGN" CELOTONE® Modulo

PERFORATED MINERAL FIBER TILE



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Serene pattern PROTEC-TONE* Mineral Fiber Tile, one of the family of fire-rated acoustical products "by Celotex."

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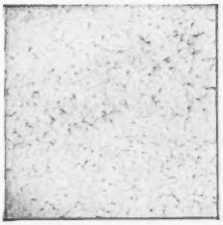

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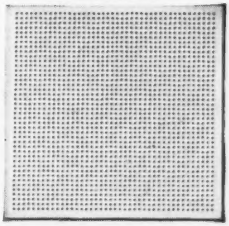

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Good fire protection is a worthwhile investment at any price. However, it is only good business to get the best equipment at the most realistic cost. This is where Viking can be of great service to you.

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from the ground up

For plant, office or warehouse; an automatic sprinkler system to meet every requirement — Wet, Dry-Pipe, Deluge or Pre-action. Engineered, manufactured and installed by fire protection experts. Pays for itself in reduced insurance costs.

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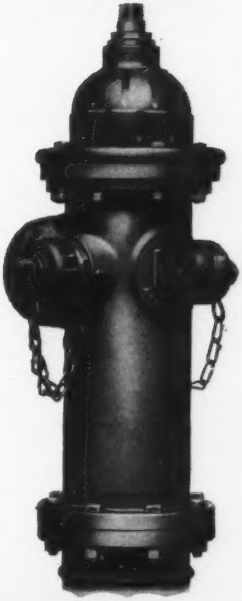
MH

COMPRESSION TYPE FIRE HYDRANT

Above: Standard Model.
Below: Traffic Model.



Although an M & H Fire Hydrant may stand idle for years, without a moment's notice it functions perfectly. Its simple rugged design and careful manufacture from highest quality materials is the reason.

Large diameter, unobstructed waterway gives high flow efficiency when large volume of water is needed to fight fire. All operating parts are bronze or bronze bushed. Furnished either in accordance with A. W. W. A. specifications or Underwriters and Factory Mutuals approved; also either standard model, traffic model or flush type. For complete information, address

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The lower photo shows how well a typical Akbar Fire Door withstood heat and flames that gutted one section of a building, fully protecting areas on the other side of the wall.

Kinnear's Exclusive
AKBAR Steel Rolling Fire Doors*

Tested, fire-proven safety features of Akbar Doors assure maximum protection at openings in case of fire.

When heat releases a fusible link, a strong push-down spring closes Akbar Doors with a positive start.

The emergency closing speed of Akbar Doors is *controlled*, for safety to building occupants.

Another Kinnear safety device prevents the steel curtain from either pulling loose at top or from falling below floor level—even if the sill burns out!

For emergency exit, Akbar Doors can be raised *after* automatic closure — and they close again automatically.

The rugged, interlocking-steel-slat curtain of Akbar Fire Doors remains coiled above the opening—out of the way and out of view — until used. Easily equipped for regular, daily service use, with either manual or motor control. Write for details on additional AKBAR advantages.

*Kinnear AKBAR Steel Rolling Fire Doors, within approved size limits, are labeled by Underwriters' Lab., Inc.

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ROLLING DOORS

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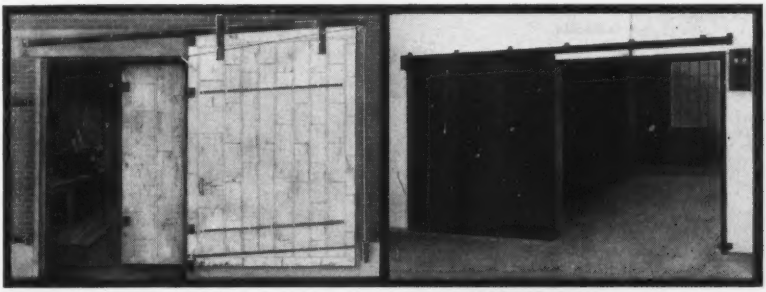
New D & H SLIDING FIRE DOORS Mean

ONE instead of TWO

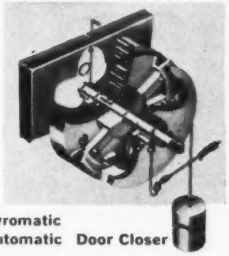
Under New 1961 Uniform Building Code for Fire Walls in Buildings



OLD TYPE DOORS. Two sliding metal clad fire doors are required for protection of 3-hour fire wall openings according to the 1961 Uniform Building Code (Int'l Conference of Bldg. Officials). Unattractive, cumbersome.

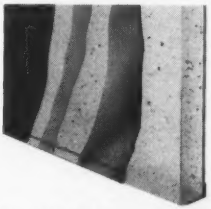
NEW SLIDING PYRODOR. After passing an official fire and hose stream test for 3-hr. rating, a SINGLE "SL" Pyrodor has been approved for 3-hr. walls under 1961 Uniform Bldg. Code standard 43-2-61 (guide card 1404.1). New flush design, pleasing appearance and automatic operation.

Outstanding Features of the D & H SLIDING PYRODOR



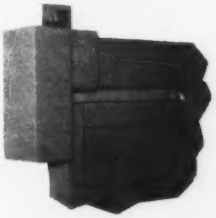
Pyromatic Automatic Door Closer

First automatic device approved and labeled by Underwriters' Laboratories. Smooth, easy manual operation at all times . . . yet fully automatic, at controlled speed, in event of fire.



Lowest Heat Transmission Solid Mineral Core

Unequalled by any other fire door construction. Impervious to moisture and dry rot . . . dimensionally stable . . . warp proof.



New Underwriters' Labeled Anti-Creeping Device

Wedging open fire doors no longer a problem. Door is held fully open . . . releases automatically.

Smooth, flush-designed Sliding PyroDors are ruggedly constructed by combining heavy gauge zinc coated and bonderized Stretcher-Leveled Steel with a solid mineral core.

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IN ALL ITS **RELIABILITY!**

Every minute of the day and night, Reliable automatic sprinklers are acting as miniature fire control teams . . . standing ready to automatically detect, sound the alarm, and extinguish fires in their incipient stages.

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For perfect FIRE CONTROL . . . Let your local Reliable Licensee show you the RELIABLE FIRE CONTROL TEAM . . . We'll see that he contacts you promptly.

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THE RELIABLE AUTOMATIC SPRINKLER CO. INC.
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automatic
ROLLING-STEEL
FIRE DOORS

Quick-acting Mahon Fire Doors (and Fire Shutters) are engineered, built and installed for your maximum advantage and safety. No other fire door offers you as much—Underwriters' Label, vertical roll-up action, manual or power operation with automatic fire closing, Bonderized slats, ruggedly made—and more. Investigate the many diverse benefits . . .

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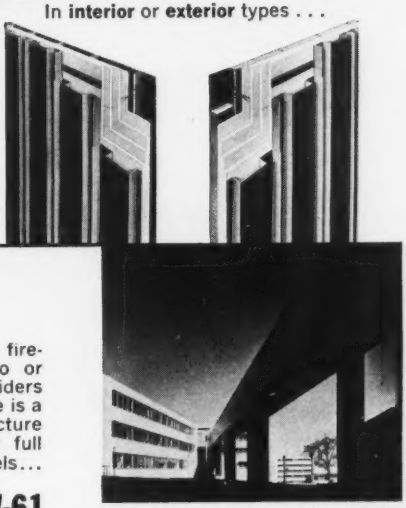
FOR BASIC FIRE PROTECTION

In **interior** or **exterior** types . . .

MAHON
Underwriters' rated
METAL-CLAD
FIRE WALLS



Mahon Fire Walls are a superior fire-protection product—rated at two or three hours—for use as interior dividers or exterior curtain-type wall. There is a type for your use . . . your architecture . . . your safety demands. For full information on these versatile panels . . .

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Univ. of Michigan Hospital uses Mahon exterior Fire Wall in this elevated walkway

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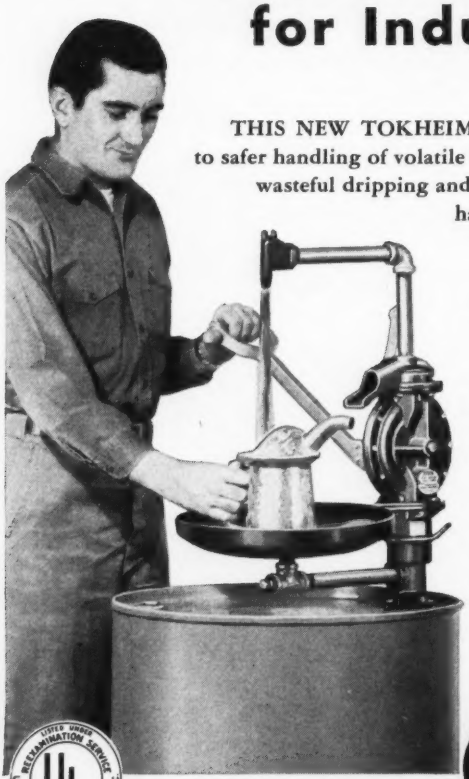

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14" HIGH

Now – thanks to the new Kidde Kompact – here's high-power fire protection at a rock-bottom price! Highest-rated, lowest-priced 2½ lb. dry chemical extinguisher on the market, the new pressurized Kidde Kompact packs as much fire-killing power as extinguishers costing twice the price. Equal to eight one-quart carbon tet units, the new Kidde Kompact mounts snugly, works simply – just lift the handle and press the lever.

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For Sprinkler Systems

Kuhns ductile iron pipe fittings—the newest development in piping—provide an extra margin of operating safety for sprinklers, high pressure lines and other vital piping systems. High structural strength and resistance to thermal shock help these fittings prevent leakage caused by vibration, temperature changes or misalignment.

"K" Pipe Lock Couplings

Listed for 800 psi by Underwriters' Laboratories, Inc., these couplings have a safety factor of five times the UL listing for 2½" through 6" and four times UL listing for 8". Sizes: 2½" through 8". Look for the "800 D" on each.

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Complete range of sizes through 12".

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Pressure ratings listed by Underwriters' Laboratories, Inc.

STEAM AND OIL AT 550°F
¼" to 3".....300 lbs.

LIQUID AND GAS AT 150°F
¼" to 1".....2000 lbs.
1¼" to 2".....1500 lbs.
2½" to 3".....1000 lbs.

*Ductile iron fittings are available in any size in Kuhns complete cast iron line, ¼" through 12".

Note: These fittings are excellent for liquefied petroleum gas systems. Look for the "DI 300" on each.

Send for our catalog or contact your wholesaler.

K

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STARGARD

Ceiling Pattern (Flush-Type) Automatic Sprinklers

☆ DECORATIVE

☆ DISTINCTIVE

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THE ULTIMATE IN FIRE PROTECTION

STAR SPRINKLER CORPORATION

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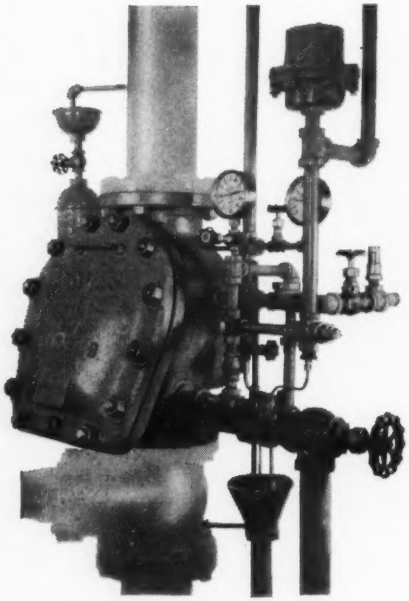
NEW IMPROVED

GRIMES MODEL B DRY PIPE VALVE



Another new GRIMES device which has been designed for functional efficiency and simplicity in maintenance. The full size cover plate makes the entire interior of the valve accessible. Cleaning and re-setting takes but a few minutes. If maintenance is your responsibility specify "Grimes". For more information write Raisler today.

GRIMES DEVICES ARE APPROVED BY ALL INSURANCE INTERESTS

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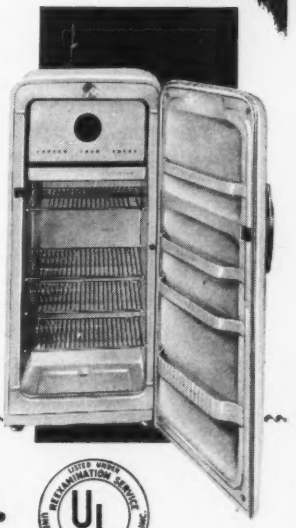
For safety to personnel, for protection of valuable experimental materials, for security against extensive property loss, more decision-makers in more fields are choosing Explosion-Proof Refrigeration every day. They encompass a wide variety of Industrial research laboratories, high schools, universities and hospitals everywhere.

KELMORE is the largest manufacturer of standard-size, explosion-proof refrigerators. **It is the only refrigerator U.L. listed for hazardous locations Class 1, Groups C & D.** KELMORE refrigerators are safe for use in flammable vapor-air atmospheres described in the National Electrical Code (NFPA No. 70) under these groups.

These refrigerators have no source of ignition on the inside of the unit. All arcing devices are located outside and are installed in an explosion-proof motor compressor housing. Wiring and the power-supply switch are also explosion-proof. Quality constructed, they will give you years of trouble-free SAFE service.

Available in 4 and 10 cu. ft. sizes. Specifications and complete technical literature available on request.



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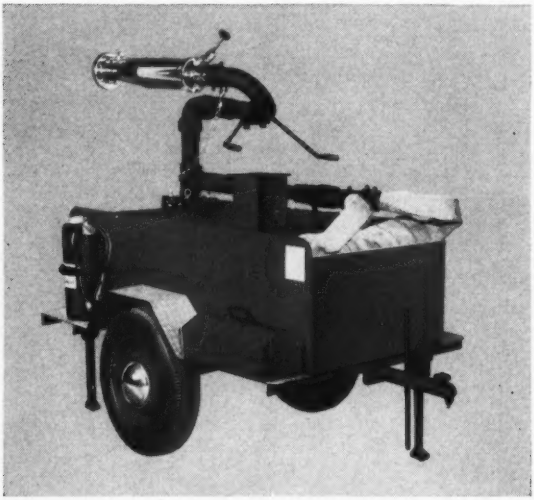

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Need an inexpensive utility trailer built to meet specific needs? National Foam has it!

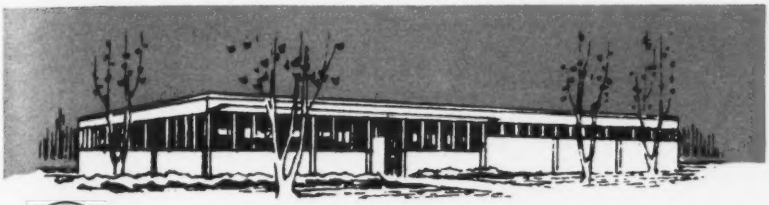
Here's a versatile, variable vehicle designed so that it can be custom-equipped to fit the requirements of any user . . . industrial, municipal, or volunteer.

Your choice of tank capacity: 100 gallons or 150 gallons. Extendable drawbar makes it easy to pull by hand. There's also a ball-and-socket hitch for towing. Capacious bins, for fire hose or accessories, are built-in fore and aft.

Maybe your situation calls for still another variation . . . including many outside the fire protection field, such as weed killing. National Foam's engineers are ready to help with specifications and designs. Send your inquiry today.

National Foam System, Inc.

West Chester, Pa.



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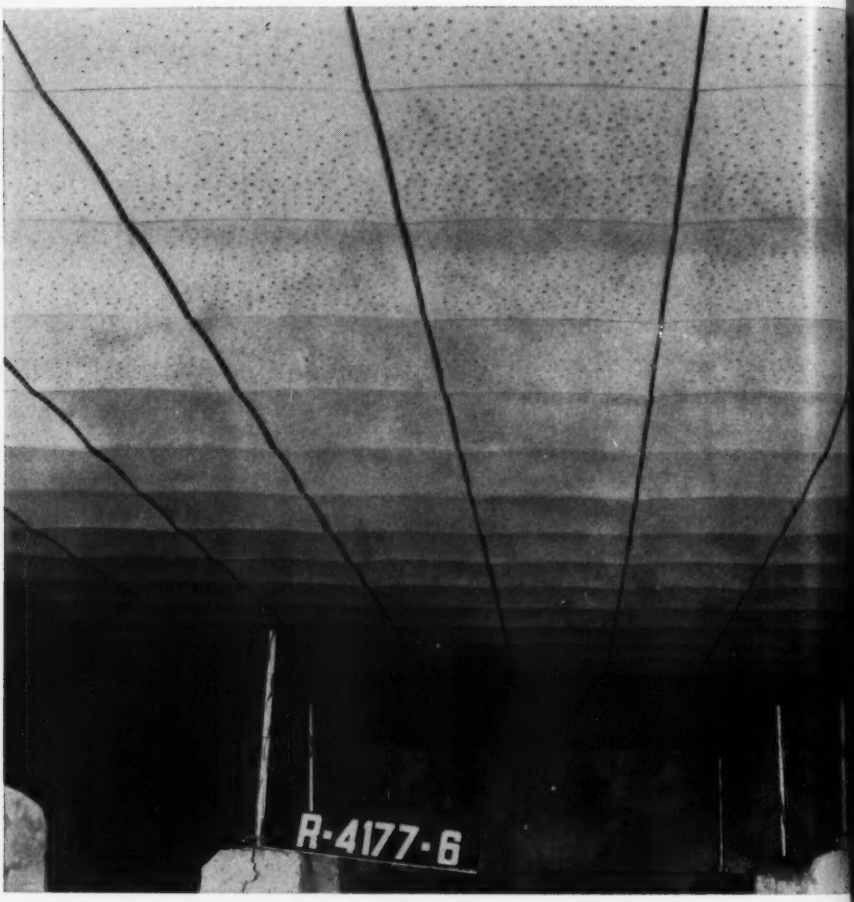
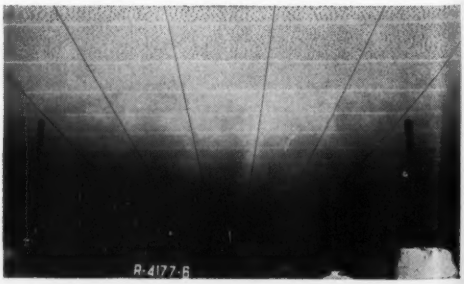


The ceiling pictured above is Armstrong Acoustical Fire Guard *after* four hours' exposure to scorching flames and temperatures reaching 2000 degrees (UL test R-4177-6). It graphically shows how the first and most widely tested fire-retardant acoustical ceiling tile protects structural components above from flames and heat—for up to four hours.



Acoustical Fire Guard ceiling installed in actual test furnace, prior to beginning the four-hour UL test.

Here's Armstrong Acoustical Fire Guard after four hours' exposure to scorching flames and temperatures reaching 2000 degrees

THE TEST: This photograph shows the exposed surface of an acoustical ceiling installed in the actual test furnace – *after* four hours' exposure to flames and temperatures reaching 2000 degrees. The ceiling is Armstrong Acoustical Fire Guard after completion of Underwriters' Laboratories, Inc., test R-4177-6.

Exposure to these extreme conditions produced some "dishing" of the tile and separation of joints. But the tongue on Acoustical Fire Guard tile effectively bridged this separation, blocking the passage of flame and resisting the transmission of heat. Protected by the Fire Guard ceiling, the metal suspension system held all tiles firmly in place.

THE RESULT: floor and ceiling design #21, incorporating a ceiling of 12 x 12 inch Acoustical Fire Guard tile, will afford four-hour protection against the passage of flame or dangerous transmission of heat. Other floor-ceiling asemblies using Acoustical Fire Guard tile and the new lay-in ceiling system have earned ratings of from one to four hours. (See table below for UL ratings commonly used to meet code requirements.)

For full details about either Acoustical Fire Guard tile or lay-in units, call your Armstrong Acoustical Contractor (he's in the Yellow Pages under Acoustical Ceilings), or your nearest Armstrong District Office. Or write to Armstrong Cork Company, 4207 Woodbridge Street, Lancaster, Pennsylvania.

HERE ARE SOME OF THE UL RATINGS FOR ACOUSTICAL FIRE GUARD MOST FREQUENTLY USED TO MEET FIRE CODE REQUIREMENTS:

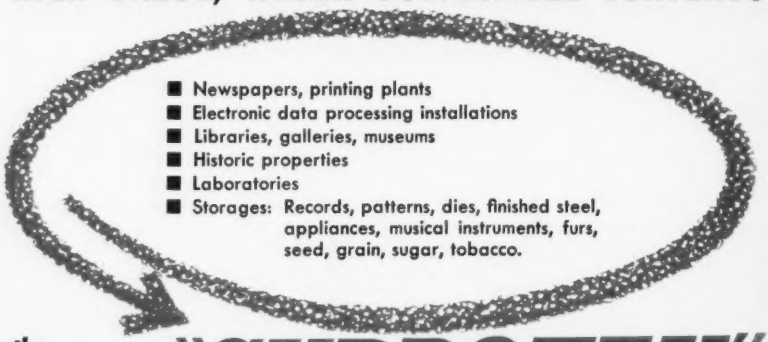
Fire Guard Lay-In		Fire Guard Tile	
Floor and Ceiling Design	Rating	Floor and Ceiling Design	Rating
#30	2 hours (Beam—3 hours)	#31	4 hours
#13	2 hours (Beam—3 hours)	#21	4 hours
#21	2 hours	#8	2 hours
#8	1½ hours	#7	1½ hours
		#9	1 hour

Armstrong ACOUSTICAL CEILINGS

First in Fire-Retardant Acoustical Ceilings

For your EXCEPTIONAL HAZARD OCCUPANCY

HIGH VALUE, WATER VULNERABLE CONTENTS


■ Newspapers, printing plants
■ Electronic data processing installations
■ Libraries, galleries, museums
■ Historic properties
■ Laboratories
■ Storages: Records, patterns, dies, finished steel, appliances, musical instruments, furs, seed, grain, sugar, tobacco.

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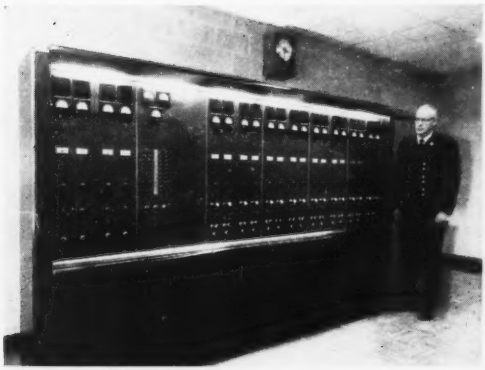

In Flint, Chief Pratt will tell you

Compactness, Higher Capacity Key Flint's New Gamewell System

"We wanted an up-to-date, highly efficient alarm center in Flint," states Elmer L. Pratt, Chief of that Michigan city's fire department, "and Gamewell gave it to us. Not only is the new Gamewell system tops in efficiency and reliability . . . it actually costs us less than a leased telephone system."

Although Flint's new system has a greatly expanded capacity for additional circuits, it occupies much less space than the old system. It ties together the city's 290 street fire alarm boxes plus master boxes installed in major public buildings, schools, hospitals and industries. Scant seconds after any box is pulled, Flint's entire fire defenses are alerted to the location of the fire.

Chief Pratt recalls an incident that dramatically illustrates one of the system's most outstanding features — the fact that it is Three-Fold*. "We had a case where a car knocked out a circuit and burst into flames. A witness ran to the box and sounded the alarm. Though the circuit was broken, the alarm was received at the center. We wouldn't have received that alarm with the old system."

Make certain that your fire safety authorities know what positive steps can be taken toward reducing loss of life and property. Gamewell will be happy to assist you with your fire reporting problems. Write to THE GAMEWELL COMPANY, 1296 Chestnut Street, Newton Upper Falls 64, Massachusetts. A Subsidiary of E. W. Bliss Company.

*T. M. Registered

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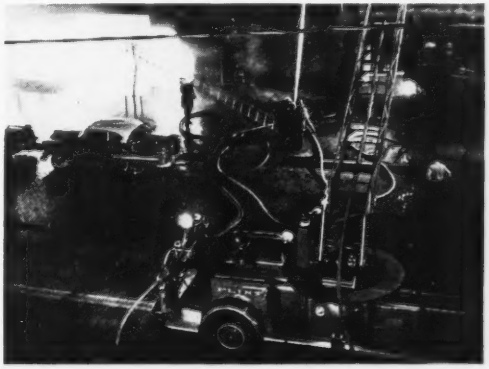
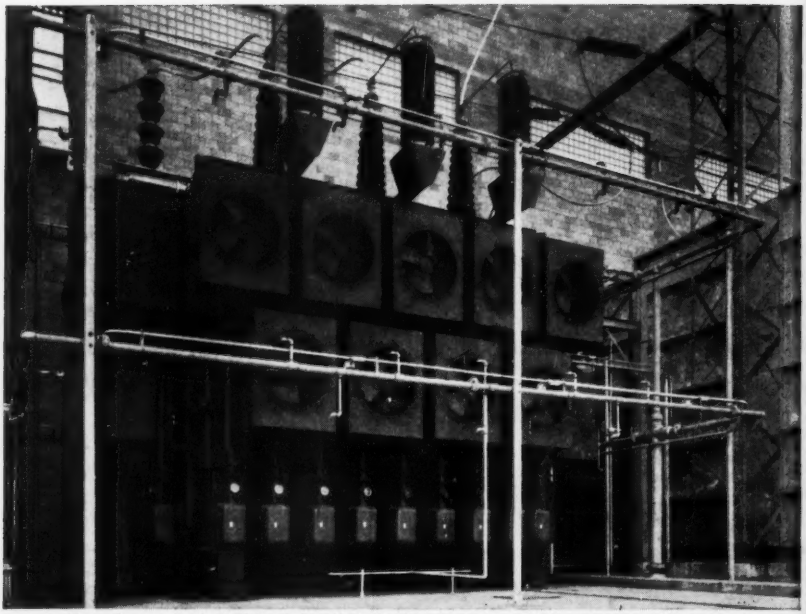
FIRST...WHEN SECONDS COUNT





Transformer protected by Grinnell Water Spray System at 450,000 KW Unit No. 5 of American Electric Power Company's Phillip Sporn Station at New Haven, West Virginia.

Grinnell fire protection systems guard one of America's largest power stations against shut-down by fire!

Grinnell Water Spray systems protect two main transformers, two auxiliary transformers, the reserve auxiliary start-up transformer, the vital sections of the coal conveyor system, cable trays, auxiliary boiler feed pump oil tank, and the stator and seal oil unit at Phillip Sporn Station. Grinnell Foam-Water system protects the basement floor area in the vicinity of the turbine pedestals.

Grinnell-installed Carbon Dioxide systems protect the main boiler feed pump oil tank and the turbine oil and lube oil tank rooms. Grinnell-installed Dry Chemical systems protect the main turbine bearings, the stop and intercept valves, and the pedestal cavity behind the front standard.

Remember, whatever your fire protection needs, there's a Grinnell system just right for you. Send for the reprinted article, "How Good Is Your Fire Protection?", which details fire protection for generating stations.

Write to Grinnell Company, Providence 1, Rhode Island.

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